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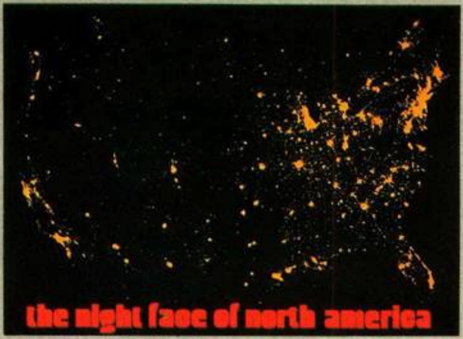
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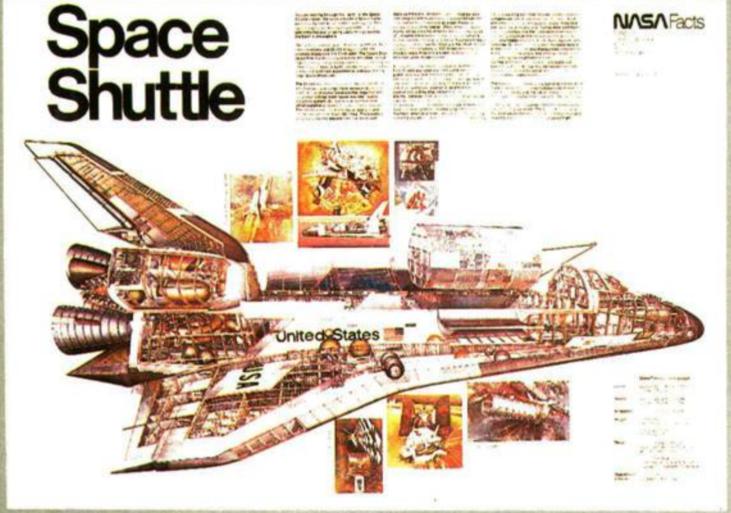
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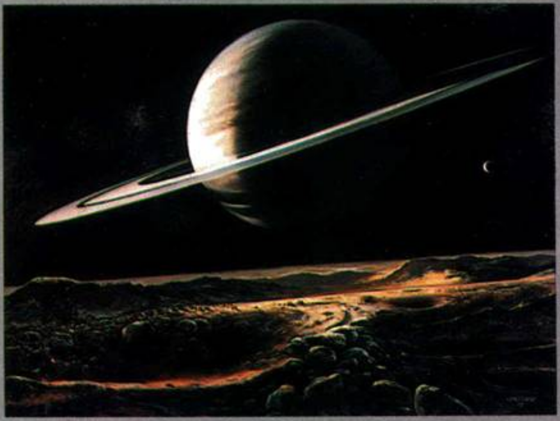

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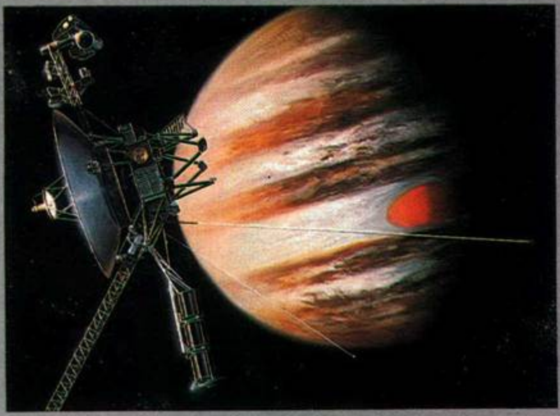

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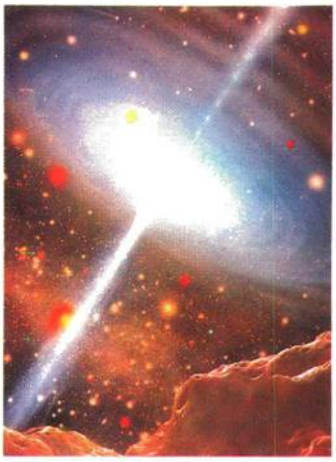

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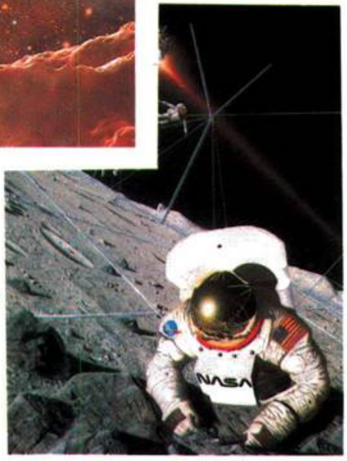

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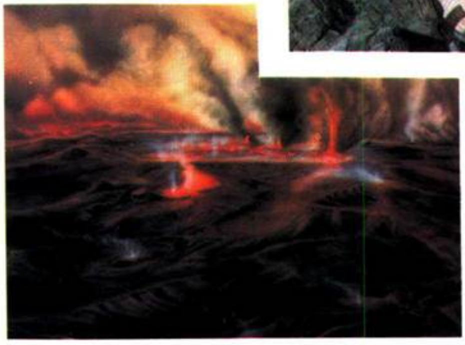

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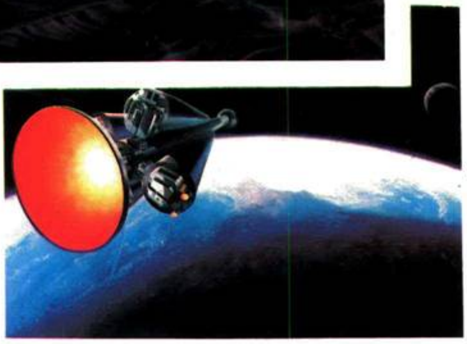

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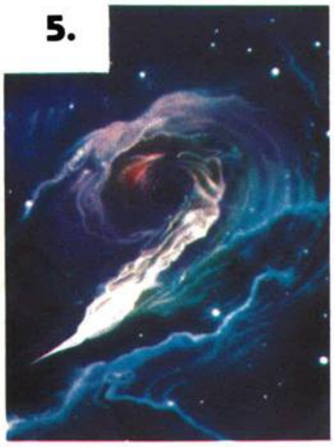

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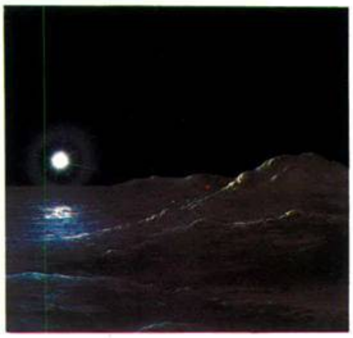

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Cover: The mysterious core of our Galaxy has remained hidden from us until recently. Now for the first time in history, astronomers are beginning to pierce the veils surrounding the center of our cosmic home, revealing an exotic realm of immense power. This month ASTRONOMY takes you on a journey of discovery to the center of the Galaxy. In Stellar Frontiers we return to Earth for a look at the possibility of some cosmic catastrophe upsetting the delicate balance of forces which make life on this planet possible. Cover painting by Mark Paternostro; photo on these pages courtesy of Hale Observatories.

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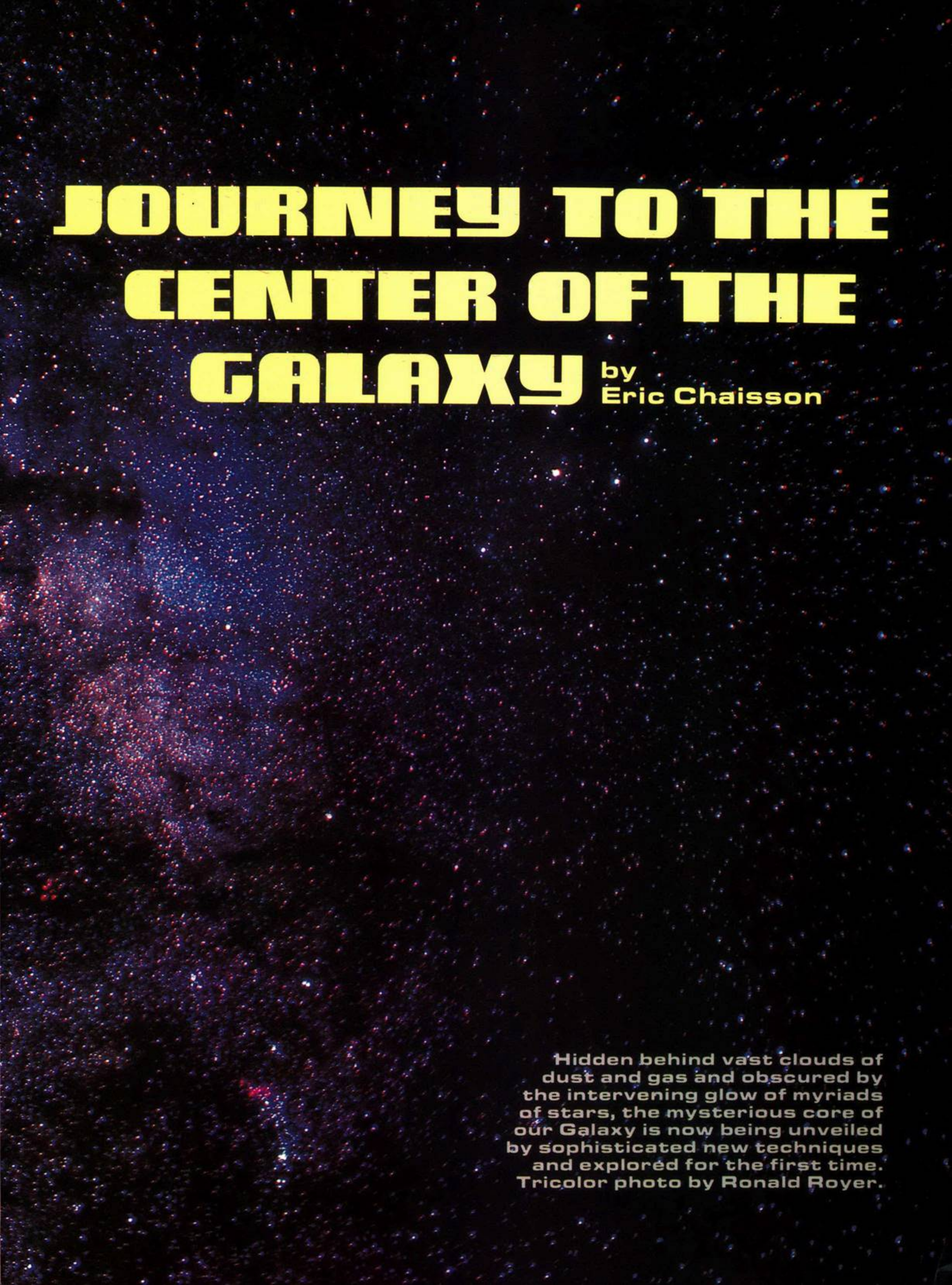
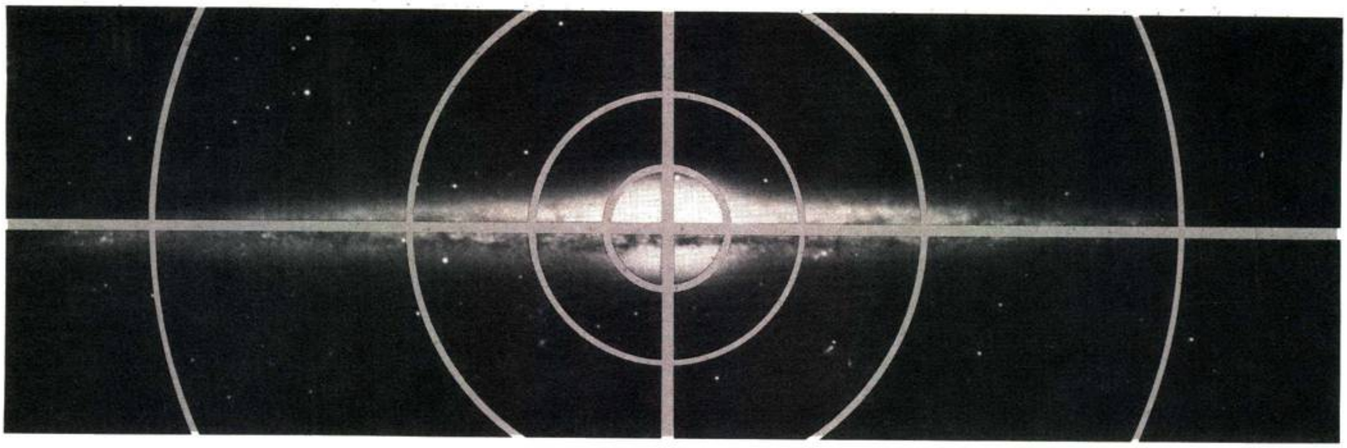
JOURNEY TO THE CENTER OF THE GALAXY

by
Eric Chaisson



Hidden behind vast clouds of dust and gas and obscured by the intervening glow of myriads of stars, the mysterious core of our Galaxy is now being unveiled by sophisticated new techniques and explored for the first time.

Tricolor photo by Ronald Royer.

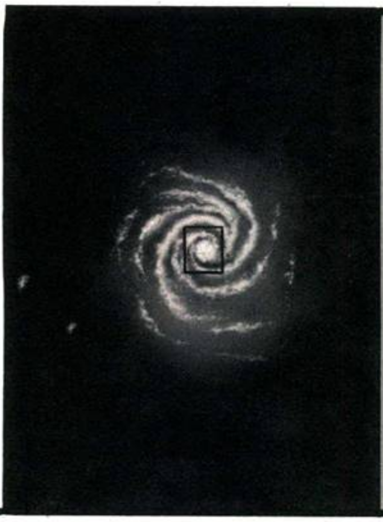


Sporting elliptical shapes like huge cosmic footballs or complex spirals like pinwheels, galaxies are the genuine giants of the cosmos. Replete with literally hundreds of billions of stars bound loosely by gravity, each galaxy harbors more stars than people who have ever lived on Earth. Silently and majestically, the galaxies twirl in the vast reaches of the universe, simultaneously imparting a feeling for the immensity of the universe and for the mediocrity of our position in it.

Absolutely titanic, these systems of matter remain among the most enigmatic objects in the known universe. We understand neither how galaxies originate nor how they evolve. We marvel at the outbursts of their active members, and gasp at the power of their suspected relatives, the quasars.

For decades, astronomers have examined, monitored, and modeled galaxies. From our vantage point here on Earth, numerous experiments have enabled us to probe the size, shape, and disposition of these gargantuan assemblages of stars, gas, dust, and radiation. Now, as astronomers invent methods to probe their central nuclei, we seem poised on the threshold of fathoming the secrets of the galaxies. Not surprisingly, the key to their understanding may lie deep within their hearts.

Our Milky Way Galaxy is one such assemblage of stars, gas, dust, and radiation. It's an abode for the Sun, the Earth, and the stars we know best. Grand understandings often begin at home. Even here, though, there are problems.



A somewhat simplified rendition of our Galaxy's morphology, this artist's conception is based on many pieces of data acquired at observatories around the world. The Sun's location is marked by a yellow dot. Painting by Lola Chaisson.

300,000 l.y.

Eyeballing the Milky Way

Like tourists who often appreciate foreign attractions a good deal more than their own historical sites back home, or like planetologists who seem to understand the Moon better than the Earth, in some respects we know more about other galaxies than about our own. The problem is that we're stuck *inside* the Milky Way — the view of most extragalactic objects is reasonably clear, while that of our own galactic backyard is considerably muddled.

What do humans know about the Milky Way Galaxy? What has twentieth-century research revealed about the overall structure of our galactic home? In particular, what have we learned about the heart of our Milky Way, the central core of this colossal star system?

Optical studies of star clusters long ago established the existence of a more-or-less spherical halo of old stars, stretching some hundred thousand light-years across. This halo is divided into two hemispheres by a disklike layer of young stellar objects, often noted overhead on a dark night: the Milky Way. Though we can't see it fully, this so-called galactic plane is shaped like a double sombrero, nearly a hundred times thinner than its full expanse. Observational comparisons with other galaxies together with theoretical considerations support the notion that our Milky Way Galaxy is a rough spiral system like many others, stocked with hundreds of billions of stars unevenly interlaced throughout a chaotic hodgepodge of interstellar gas and dust.

Half a century ago, these were inferences. The ubiquitous galactic dust messed up the view, and kept astronomers literally guessing about our Galaxy. Many of these inferences were hard to swallow. After all, hardly more than fifty years ago, our brightly shining and oft-worshipped Sun was regarded by science and society alike to inhabit the center of not only our Galaxy, but the whole universe as well. So it was something of a shock when the American astronomer Harlow Shapley proved in the 1920s that the Sun resides neither in the middle of the halo of old stars nor in the center of the disk of young stars. Indeed, our star and its system of planets are not only removed from the hub of the universe, but they are also far from the center of the Milky Way.

Despite our inauspicious location, astronomers can observe huge blobs of matter comprising bright stars and dim clouds, and they have attempted to map the broad features of our Milky Way. Clearly a task of astronomical effort, construction of such a map would be nonetheless straightforward if only we could travel around the Galaxy like the terrestrial explorers of the past few centuries traveled around the Earth, discovering continents, charting coastlines, and mapping the general layout of our planet.

Galactic cartography would also be easier to unravel if we could get above it all, like the Earth-orbiting satellites that gaze at our planet, capturing its whole splendor in a single snapshot. However, we cannot now journey about the Galaxy, let alone travel far enough away from it to glance back at its full grandeur. Nor is it likely that our descendents will ever have such an opportunity, despite what will surely be a greatly increased technological prowess. The Galaxy is just too vast, the myriad objects within it just too remote. With light velocity the ultimate speed limit in the universe, it's unlikely that anyone, even Earth's most courageous astroexplorers, will ever conduct on-site measurements on the far side of the Galaxy!

Milky Way research is confronted with distances so enormous that they quite possibly will never be traveled by human beings. The basic problem is somewhat analogous to a restricted attempt to decipher the location of crosswalks, benches, monuments, and trees in a large public park. Confined to one bench near an outer perimeter, and prohibited from walking, riding, or otherwise sauntering around, mapping the park's layout becomes a formidable task indeed. Clearly, any resulting map would be subject to distortion, obscuration, and incompleteness. Especially grand and intriguing objects — such as monuments near the park's center — are likely to be shrouded in considerable mystery, for they resemble none of the trees, walks, or benches near our edge of the park.

And so it is with our Milky Way Galaxy. Confined to the galactic suburbs, we strain to fathom the myriad objects in this part of the universe we call our galactic home. While most people sleep, astronomers every night attempt to identify, catalog, and place various galactic objects into perspective. First, we seek a map of the Galaxy, not because our descendents are likely ever to use it while traveling about, but because humans need to know more about our place in the cosmic scheme of things. Second, we wonder what sort of matter might exist at the special, central, and perhaps unique realm at the heart of the Milky Way.

Radio studies have confirmed the optically inferred impression of our Galaxy, further elucidating the Milky Way's grand design by providing fleshy data for the skeletal structure. Long-wavelength radiation emanating from quantum changes in neutral hydrogen atoms and carbon monoxide molecules has enabled researchers to sketch the full spread of the interstellar gas throughout the galactic disk. Unlike short-wavelength visible light that is heavily scattered by galactic dust, long-wave radio radiation can propagate virtually unhindered through the galactic fog.

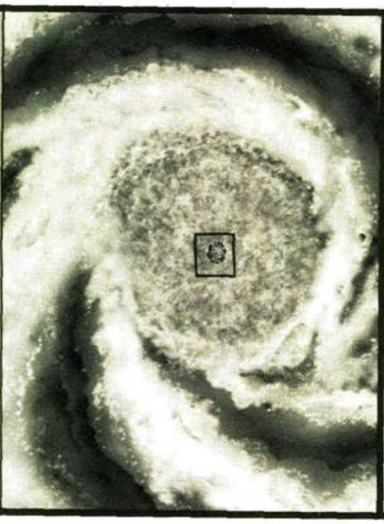
Astronomers transmit no radiation to study the Galaxy. Radio and infrared telescopes just collect and focus radiation naturally emitted by cosmic matter having any heat. This radiation is then detected, amplified and massaged, analyzed, and interpreted. The data form a map of the Galaxy.

A Journey to the Center

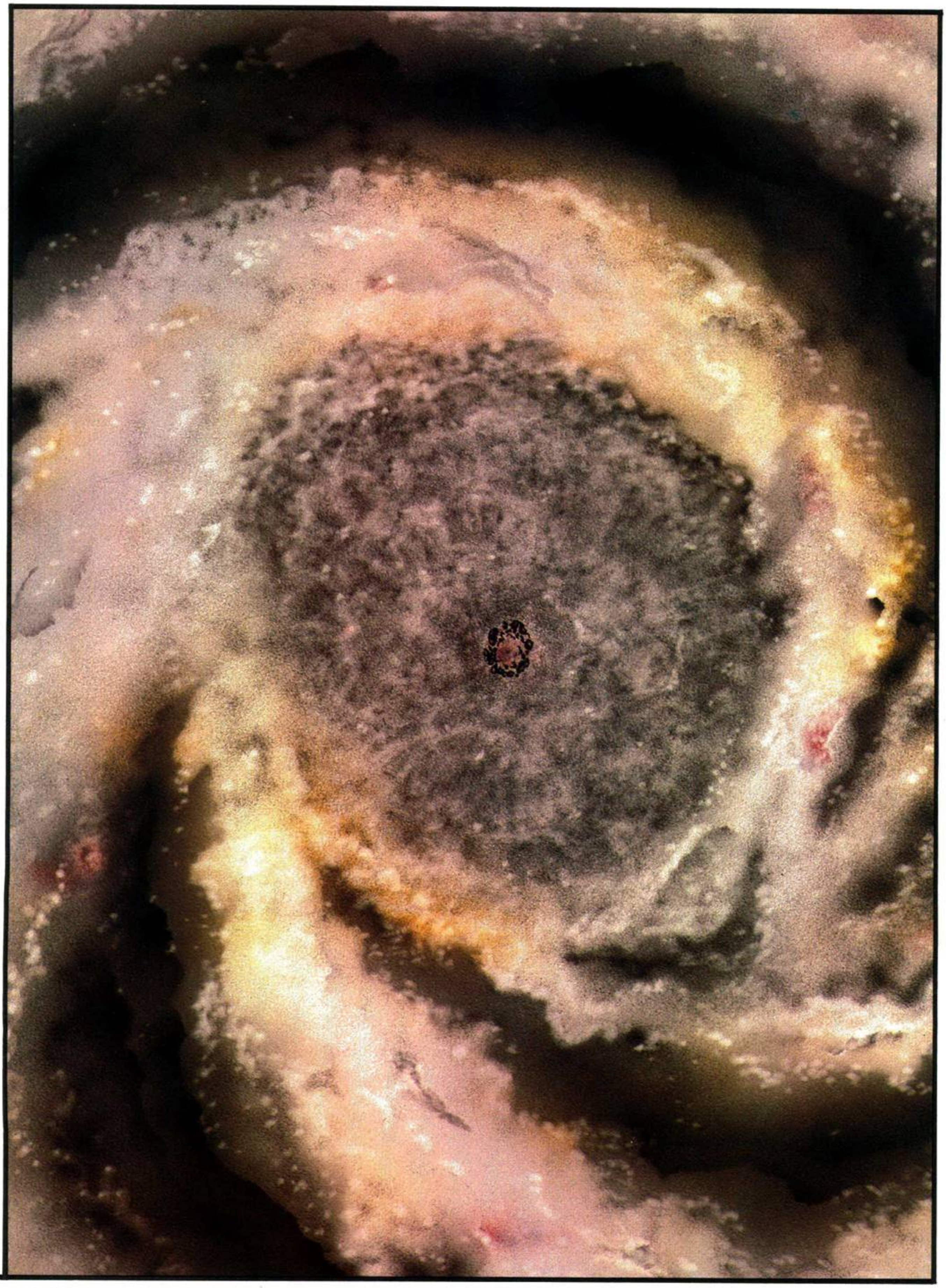
Now let us assume that we can, despite expectations, span the vast reaches of intergalactic space in our own cosmic starship. What would it be like to journey to the center of our Galaxy from a point 300,000 light-years directly above its huge disk? What sights would we see as our ship hurtled down upon this gigantic assemblage of organized matter? What would we discover as we approached the mysterious core, the center of the Milky Way, forever hidden from our eyes here on Earth? Thanks to a number of sophisticated modern instruments and techniques, we can now say with some confidence what such a journey would reveal.

From 300,000 light-years out, at the beginning of our trip, we can look down on the flat galactic disk as a whole. The spiral arms glow with gargantuan numbers of bluish-white stars. Much of the galactic gas and dust is invisible, extending far beyond the 100,000 light-year region of luminous matter shown. The full extent of the Galaxy may actually exceed the view on our ship's screens, which spans from top to bottom 100,000 parsecs or about 300,000 light-years. Even the Magellanic Clouds, once thought to be dwarf satellite galaxies, are now regarded as part of our Galaxy.

A spiral structure is clearly evident on our viewscreen. Although invisible at this distance, its feeble gleam overwhelmed by the massed glow of millions of far more luminous stars, we can pick out the location of our Sun because we know that it is a member of the Orion Arm, which some researchers regard as merely a spur extending from the major Cygnus Arm. Farther out lies the Perseus Arm, while closer to the center we can see the sweep of the Cygnus Arm. Even closer to the galactic core lies the Sagittarius Arm, and inward from that, the so-called Three-kiloparsec Arm. This last feature is only about



Spanning a distance of 30,000 light-years from top to bottom, this view of the galactic center is nearly filled by the vast circular sweep of the Three-kiloparsec Arm, whose interior is filled with thin, cool gas. Painting by Lola Chaisson.



30,000 l.y.

12,000 light-years from the center.

Each of the brightly whirled patterns we see contains a mixture of young stars as well as lots of gas and dust. Very energetic stars ionize nearby gas for light-years across, creating hot (10,000° K) nebulae. Those close to the Sun are directly visible back home from Earth, while those more remote and invisible can be probed by means of their radio emission. Much of the gas remains neutral, thin, and cool, containing only 10 particles/cubic centimeter at 100° K. Some of the gas is clumped into interstellar clouds, including many particularly dense and cold molecular clouds having 1,000,000 particles/cubic centimeter at a temperature of only 10° above Absolute Zero.

Our ship begins to move in closer — much closer — until we find ourselves ten times nearer the galaxy's brilliant heart, 30,000 light-years away. Already we find that our approach has completely removed the Sun and most of the spiral arms from our viewscreen. Here, the Three-kiloparsec Arm is prominent, looking more like a ring than a bona fide arm. Radio studies back on Earth imply that it is indeed more toroidal than spiral. Whichever it is, the bright regions we see are known to be composed of young stars embedded in neutral gas and ionized matter as well as lots of dust. This entire galactic feature, roughly midway between the Sun and the galactic center, is both rotating and expanding.

Hidden from our view by the canopy of stars is the nuclear bulge of the galaxy. Inside the 25,000 light-year diameter ring we see a darkish region, thought to be largely composed of neutral gas that is thin, about 10 atoms/cubic centimeter, and cool, at a temperature of about 100° K. Chances are good that the gas is clumped or mottled, though not contracted into well-defined nebulae or clouds; radio and infrared observations from Earth show no evidence for strong sources like those usually found in the arms. There are, however, plenty of stars, the stellar density in that region being many times greater than out near the Sun. One might get the impression — perhaps correctly — that the expanding ring swept away much of the dense gas. Alternatively, the rate of star formation in this inner part of the Galaxy might be so great that most of the available matter has simply been already used to form those stars.

As we sweep in again ten times closer, we see that this cool gas is lightly clumped and generally wispy. Coming into clear view now that we are only 3000 light-years from the nucleus is another ring of galactic matter. No portion of this ring can be optically observed from the vantage point back home in our solar system — the entire structure was delineated during the 1970s only by means of radio and infrared techniques.

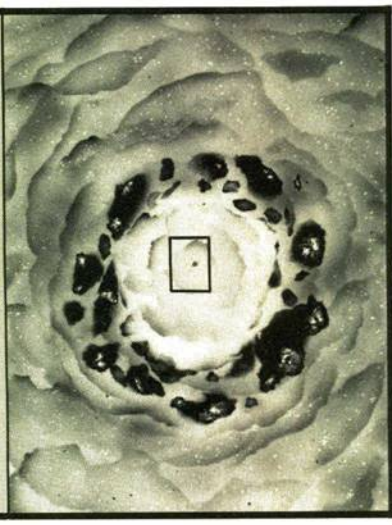
The ring itself, some thousand light-years across, is loosely composed of giant molecular clouds, looking much like big black blotches. Within, nearby, or somehow associated with the giant molecular clouds are numerous gaseous nebulae, which show up on our viewscreen in strong red and bright white. Though dwarfed by the molecular clouds, the nebulae have also been examined from Earth through the radio radiation they emit. All in all, these clouds and nebulae are hardly different from those near the Sun such as the familiar Orion or Horsehead Nebulae. Together, the clouds and nebulae of the inner Galaxy form a structure reminiscent of the larger ring known as the Three-kiloparsec Arm. Once again, this inner ring is both rotating and expanding.

Remember, our viewscreen shows the galactic center as seen by a hypothetical observer in a starship swooping down on the Milky Way, looking down at the reasonably flat disk. The rings of matter near the core, perhaps tilted somewhat relative to the plane of this disk, should be really regarded as doughnut-shaped conglomerates. A better analogy might be a series of concentric smoke rings that expand from a common center of origin. This center is presumed to be the galactic nucleus, a wholly novel piece of astronomical real estate and one that forms the focus of much current research. We are now approaching this mysterious center in our hypothetical starship, and soon we shall enter truly virgin territory. Before continuing our voyage, let's pause and consider how it is that we can know what such a journey would in fact disclose.

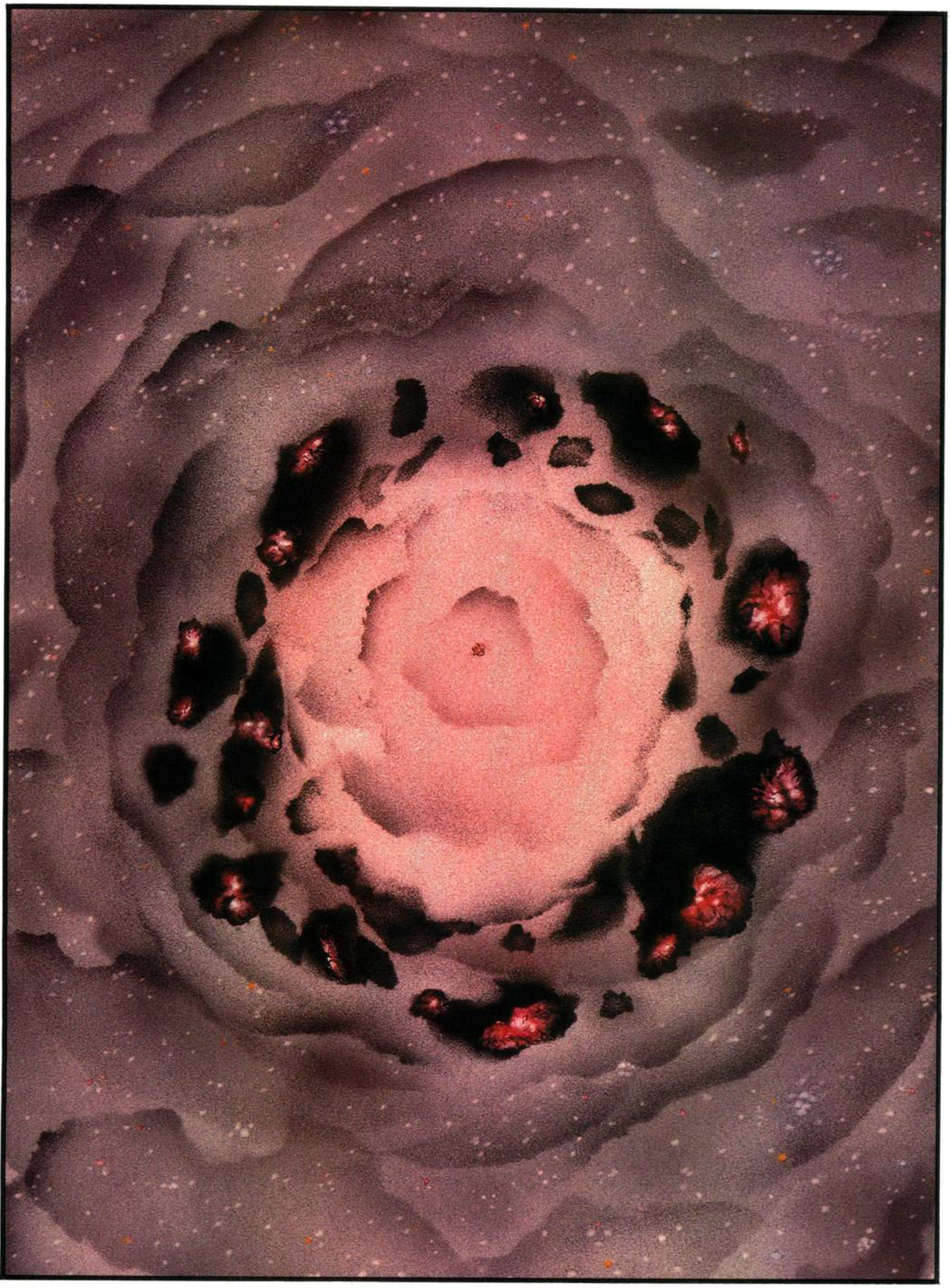
Probing the Galaxy's Heart

The galactic center embraces almost totally uncharted tracts of matter — entirely new segments of galactic acreage ripe for discovery. Pioneers having access to the technological tools capable of probing the inner sanctum of our Galaxy are now reaping a rich harvest of previously unrecognized knowledge.

How can astronomers fathom such completely obscured regions so far from Earth? Fortunately, nature itself helps out. Microscopic changes within enormous quantities of hydrogen and neon ions cause vast amounts of long-wavelength radiation to be emitted naturally and of their own accord. Other elements are doubtlessly also radiating, but these two emit in the range of the electromagnetic spectrum in which radio and infrared ground-based equipment is especially sensitive. This radiation originates in the vicinity of the galactic center and travels outward for about 30,000 years, where the marvels of Earth technology allow us to intercept a minute portion of it. Keep in mind, then, that the radiation now captured from the innermost regions of our Galaxy



Moving in ten times closer, we see another circle of material, only a thousand light-years across and composed of giant molecular clouds and gaseous nebulae, exploding out from the center like a cosmic smoke ring. Painting by Lola Chaisson.



3,000 l.y.

The Milky Way Galaxy

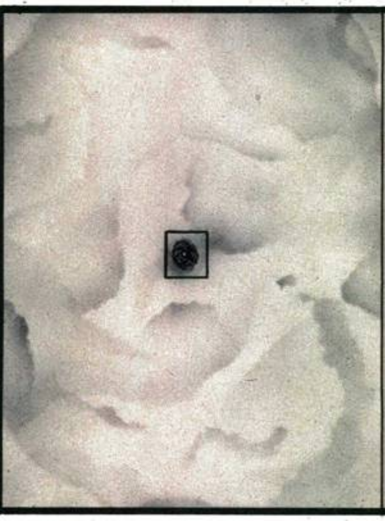
Diameter of Entire Galaxy	500,000 light-years
Diameter of Galactic Disk	150,000 light-years
Thickness of Galactic Disk	1500 light-years
Mass	400,000,000,000 suns
Number of Stars	150,000,000,000
Absolute Magnitude	-20.5
Overall Color	like a G2 star (the Sun)
Distance of Sun from Center	33,000 light-years
Rotational Speed of Sun	150 miles/second
Period of Sun (Galactic Year)	250,000,000 years
Average Distance between Stars	3 light-years
Density of Stars (Region of Sun)	1 per 300 cubic light-years
Density of Stars (Galactic Core)	3 per cubic light-year
Age	12,000,000,000 years
Elements	73% hydrogen
	25% helium
	1% carbon, oxygen, nitrogen, neon
	1% all others

The numbers given here are approximate at best. Astronomers do not agree on the exact values, and all of them are still very much under debate.

was actually launched long before the dawn of recorded history.

It takes time for cosmic messages to move through space. Even though we have learned to collect and analyze invisible radiation which is now passing through our bodies, our impression of the events at the galactic center is destined to remain forevermore delayed by several hundred centuries.

In the last few years, radio and infrared researchers have discovered that the Galaxy's heart is composed of matter in most perplexing states. Generally, there are three regions known within the innermost thousand light-years. First, there is a large zone of thin, hot, ionized gas. Within this, there is a whirlpool of dense, warm matter. And further embedded, there seems to be a small, but supermassive "something" at the very center.



Ionized gas, known as the extended thermal component, is visualized as a pinkish cloudiness surrounding the red heart of the Galaxy. The source of energy producing this vast cloud of plasma is unknown. Painting by Lola Chaisson.

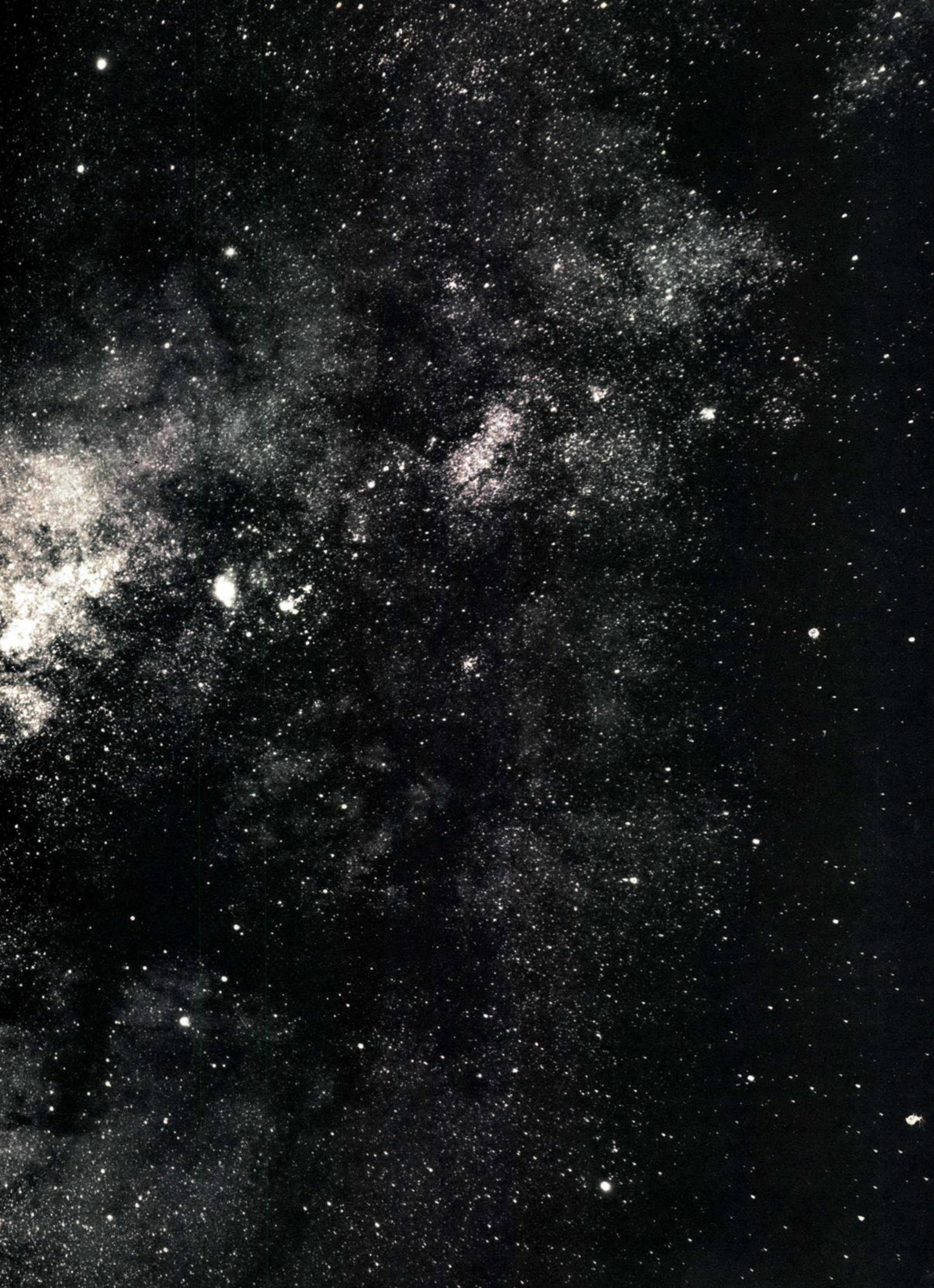
300 l.y.

At the Core

Resuming our hypothetical journey to the center of the Galaxy, we now find ourselves so close that our viewscreen spans only 300 light-years from top to bottom. The pinkish cloudiness filling the scene is due to the recently discovered ionized gas spread throughout the region interior to the molecular ring we saw earlier. There is nothing especially strange about this kind of matter — plasma of this sort mimics that of any gaseous nebula. Don't mistake it for an ordinary nebula, though. The whole zone is nearly a thousand light-years across, and harbors several hundred thousand solar masses. Furthermore, our data suggest that the whole region is either rotating somewhat, or is tormented by a great deal of turbulence.

Despite the region's color, all is not rosy. In particular, the widespread existence of this plasma is not yet fully understood. The most troublesome aspect of this large ionized zone, known to researchers as the *extended thermal component*, is its source of energetics. What causes the gas to become excited, especially throughout a region as widespread

Although the Milky Way is noticeably brighter in Sagittarius, the direction of the galactic center, the actual core itself cannot be observed in visual light. It is the huge numbers of stars between us and the center which produce the bright glow we see. Harvard College Observatory photograph.



What Kind of Galaxy Do We Live In?

Astronomers have recognized two distinctive types of galaxies: elliptical and spiral. Elliptical galaxies, by far the most numerous, lack spiral arms with their accompanying clouds of dust and gas, and appear as more or less elongated blobs. Elliptical galaxies are classified as one of eight types: E0, E1, E2...E7. The number depends on the degree of apparent elongation, E0 galaxies appearing spherical or perfectly round, while E7s are highly elongated spindles. Elliptical galaxies seem to be depleted of dust and gas, and composed almost entirely of old stars.

Spiral galaxies, with their distinctive spiral arms containing a great deal of dust and gas and new, young stars, are divided into two main classes. S (often designated SA) galaxies are "normal" spirals, with a number of arms extending out from a bright nucleus. SB spirals are the so-called barred spirals, characterized by an elongated bar extending across the nucleus. Both S (or SA) and SB galaxies are further divided into a, b, c, and d classes, ranging from tightly wound to open, very loosely wound spirals. (Intermediate classes are labeled as ab, bc, etc., and those intermediate between the SA and SB types as SAB.) Additionally, galaxies which are definitely not true ellipticals but which show no evidence of a spiral structure are classified as S0 or SB0.

Finally there are the irregular galaxies, labeled as Sm, SBm, or Im, which show no clear structure at all. Two nearby examples of irregular galaxies are the Magellanic Clouds.

Where does our Galaxy fall in this classification system? Of course we can't get out of the Galaxy to look back at it, but observations show that our Galaxy is a relatively large Sb (or possibly Sbc) galaxy — a somewhat loosely-wound spiral galaxy.

as one percent of the whole Galaxy? The same data that reveal the presence of the gas also imply that there are no young, massive stars that normally power nebular plasma elsewhere in the Galaxy.

Moving to within 30 light-years of the center, the deep red expanse at the center of our previous view is clearly evident. But what is this thing we see on our screen, uncannily resembling a human heart? It's composed of clumpy blobs of matter now under intense scrutiny by Earth-bound radio and infrared observers. Extending no more than ten light-years, or less than 0.01% of the Galaxy's size, this region is rather dense (1000 particles/cubic centimeter), warm (5000° K), ionized, and spinning. The rotation of this region is swift enough perhaps to resemble a colossal whirlpool, requiring just a few hundred centuries for a complete spin around the galactic center. This is exceedingly short compared to the 250 million years needed for the Sun to make a single trek about the Galaxy.

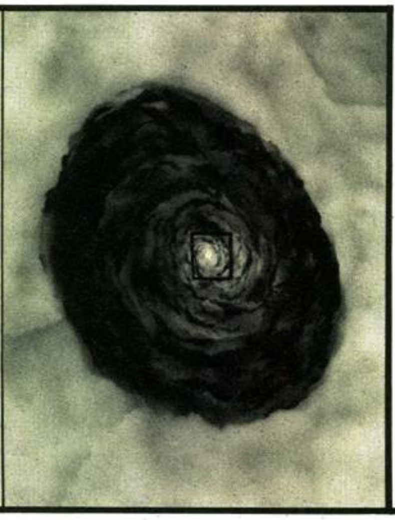
None of this structure is, of course, observed directly in visible light from Earth. Nor is the structure itself even perceived indirectly at other wavelengths. The whirlpool, like all other invisible portions of our Galaxy, results from modeling of the available data acquired from the immediate vicinity of the Milky Way interior. The geometry most consistent with recent astronomical measurements suggests a disklike region having a halo of dense, hot, spinning plasma, and a core of ionized gas that is denser, hotter, and probably rotating more quickly.

The model furthermore suggests, surprisingly, that the rotational axis of the whirlpool is not perpendicular to the general plane of the Galaxy. In fact, the whirlpool is substantially inclined to the galactic plane, causing its oblong appearance on the viewscreen of our hypothetical starship. Apparently, this central region is a distinct structure, separate from the usual environment expected near the nucleus of a typical spiral galaxy.

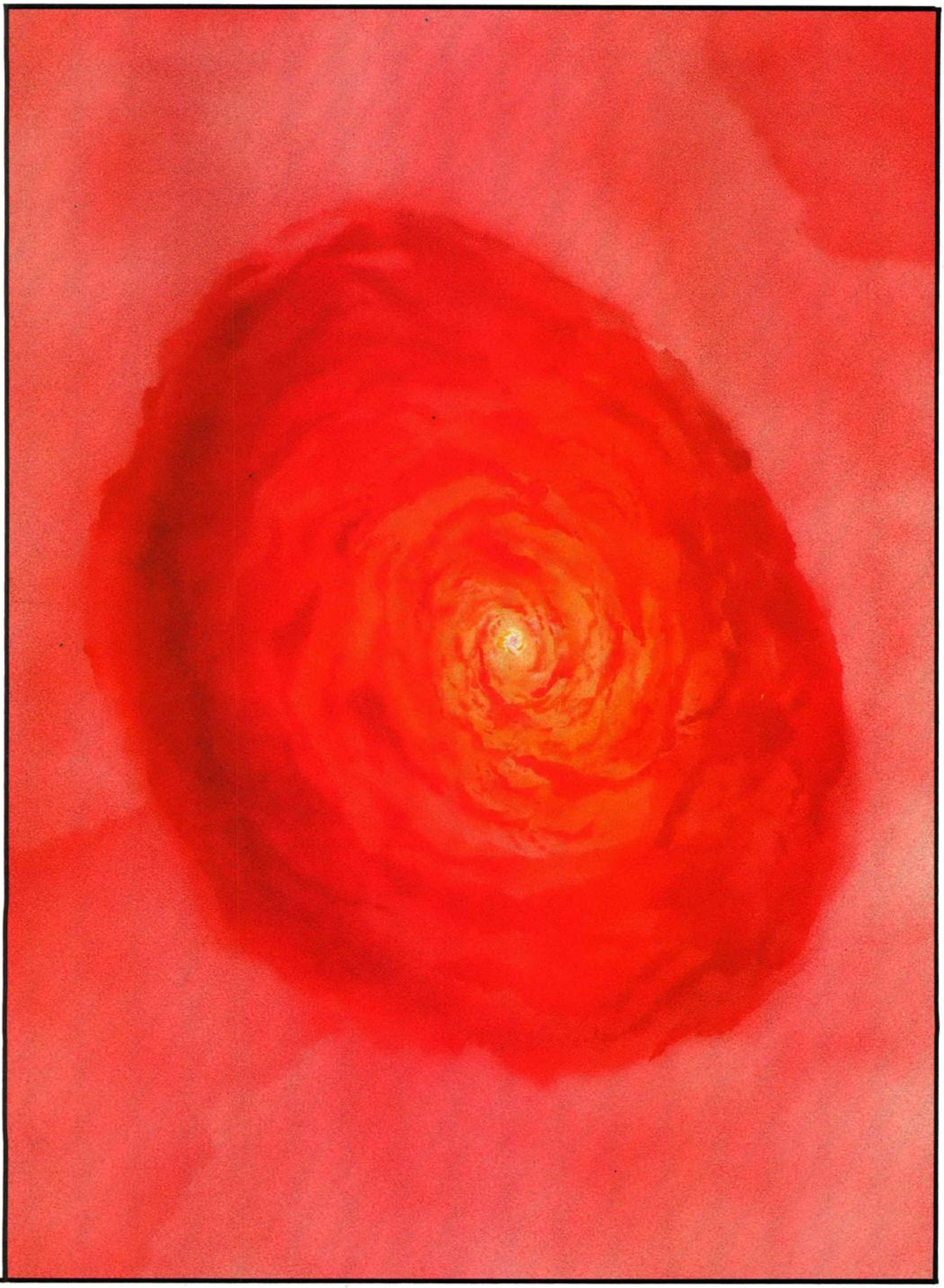
A fundamental question currently plaguing this research concerns the behavior of the whirlpool. Huge blobs of gas need something to hold them intact, lest they disperse to sheer nothingness. This is especially true of a large region of gas that is both rather hot and rapidly swirling. What keeps all this matter from being expelled into the outer reaches of the Galaxy, like mud flung from the edge of a rotating bicycle wheel?

It seems that only one force can suffice — gravity. Most astronomers now regard gravity to be the source of the whirlpool's stability. That sounds simple enough, but a straightforward calculation suggests otherwise. Why? Because a great deal more gravity, that is, mass, is needed than can be found. The required gravitational pull on the whirlpooling gas is great enough to imply the presence of a supermassive object at the center of the maelstrom. Whatever its nature, several million solar masses must be compacted within a volume about the size of our solar system!

Our closest view of the center from our starship, covering the innermost few light-years of the Milky Way Galaxy, is the most conjectural. The scene on our viewscreen, one of several possibilities, reveals hot,



Tilted with respect to the galactic plane, a vast spinning whirlpool of hot, dense gas marks the very core of the Galaxy. Astronomers suggest that some gigantic concentration of mass holds this whirlpool together. Painting by Lola Chaisson.



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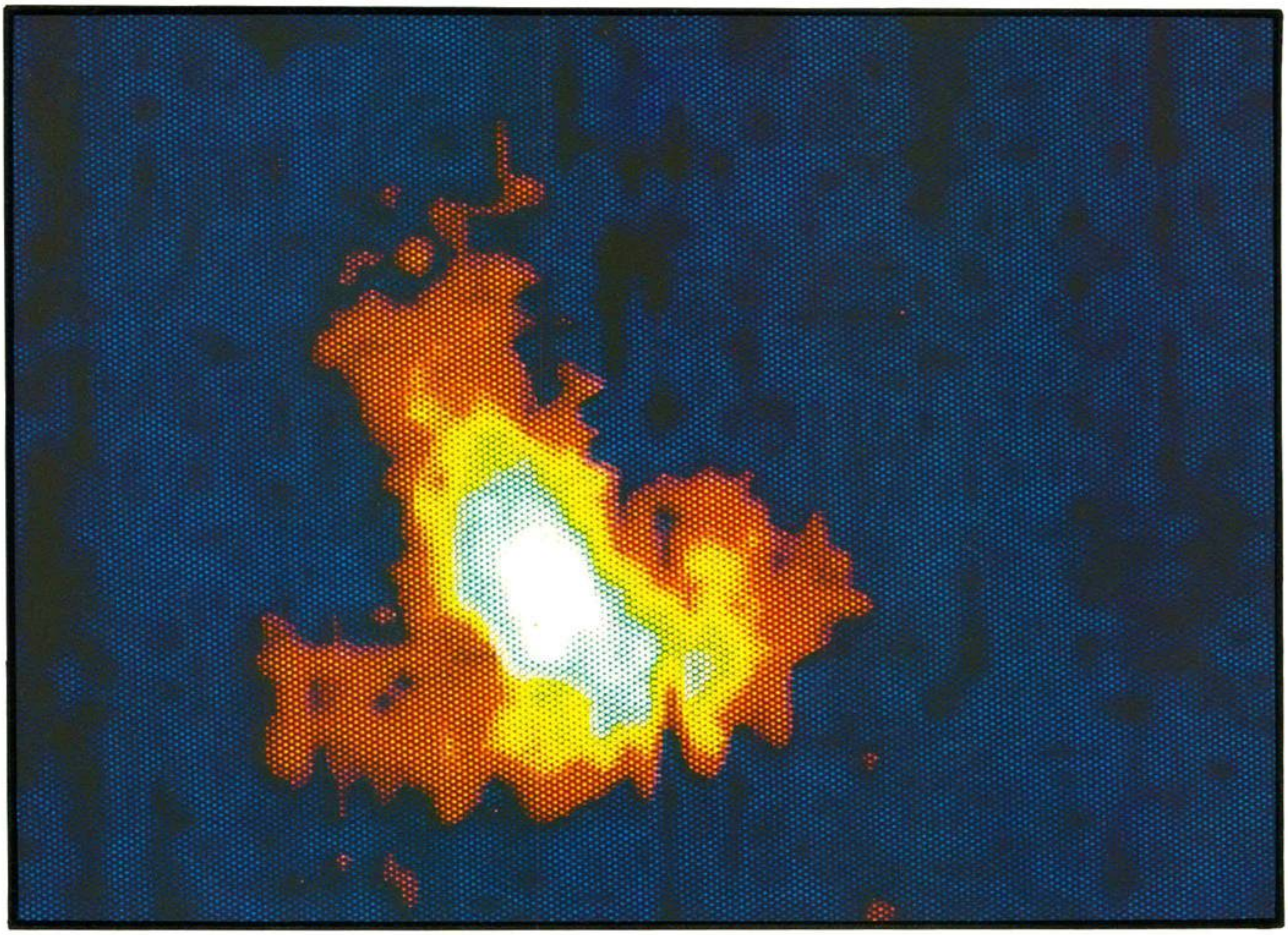


Piercing through the intervening clouds of dust and gas with the infrared eye of the University of Wyoming's 92-inch telescope, astronomers Alan Bentley and Adrian Herzog obtained this image of the galactic center at a wavelength of 10 microns. Special imaging routines developed by Gary Grasdalen and John Hackwell were employed, and the data processed on the Kitt Peak National Observatory's Imaging Processing System. Each pixel covers one square arcsecond. Photograph courtesy of Adrian Herzog and the University of Wyoming.

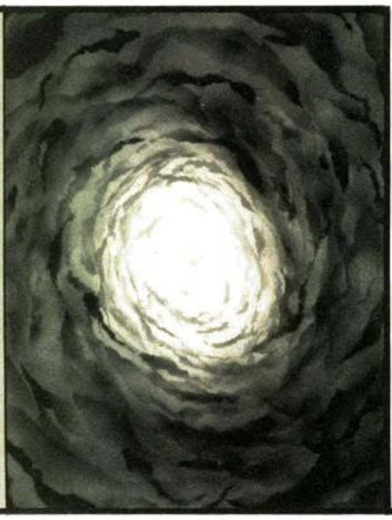
dense clumps of gas and dust along with stars rapidly orbiting beyond the clutches of a huge, supermassive black hole.

The black hole itself is far too small to be seen on our viewscreen — much smaller than the period at the end of this sentence. The white-hot center we see represents a rapidly whirling disk of gas accelerated to high velocities and heated by collisions to very high temperatures. Radio observations from Earth in the direction of the galactic center have detected a compact object, called Sagittarius A West, which is now being monitored by very-long-baseline-interferometry techniques. These studies, along with X-ray observations recently made of this same object by an orbiting spacecraft, lend credence to the type of model seen on our hypothetical journey to the center.

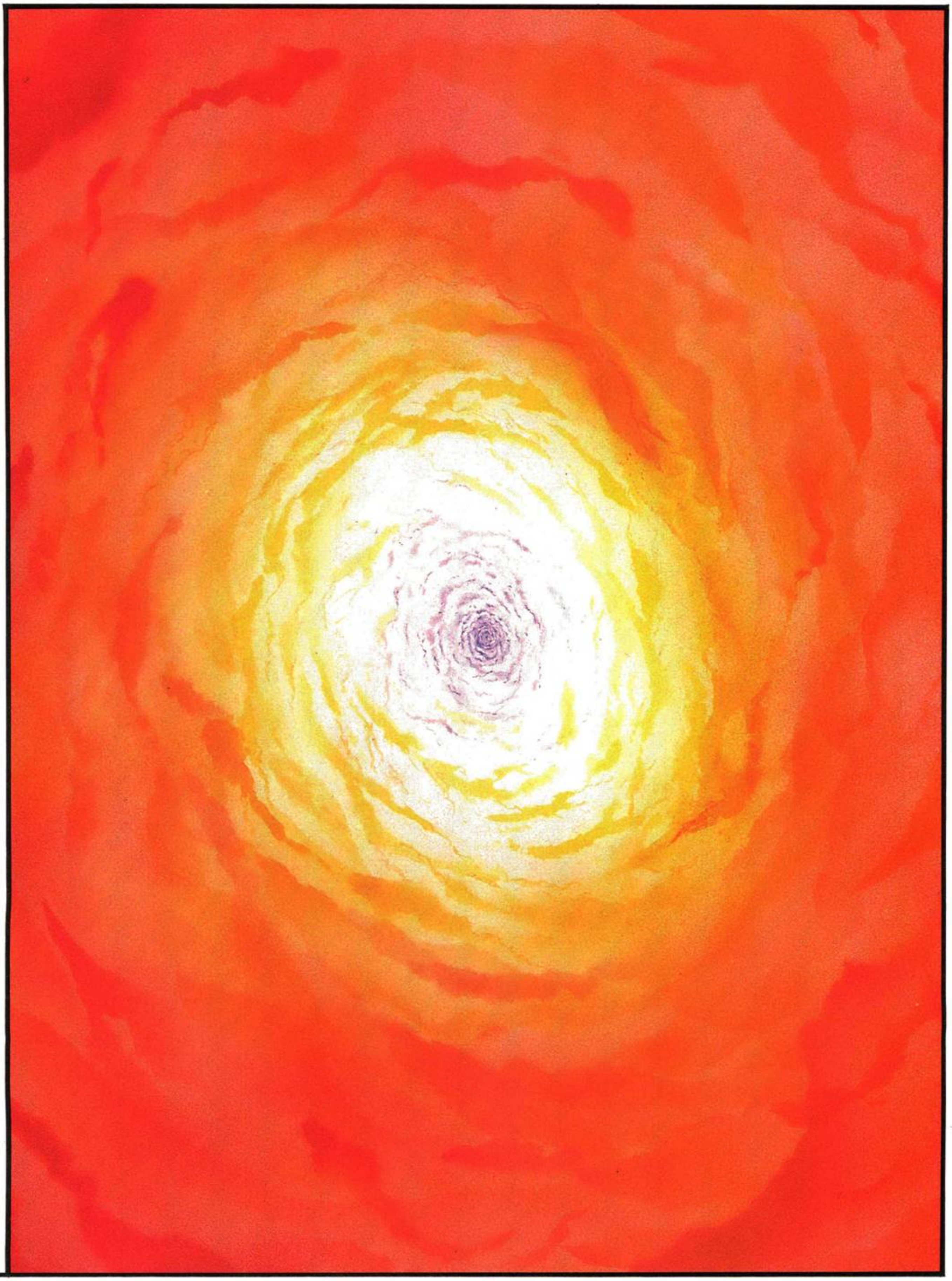
Lurking Black Holes?

Is it reasonable that a black hole, especially a supermassive one, exists at our Galaxy's center? Sure — in fact, this might be the logical place to find one. Black holes may well be the dominant residents of the cores of all galaxies, including quasars.

Galactic nuclei are expected to be massive, ultracompact regions quite unlike anything else in their parent galaxies. After all, every parcel of matter in the galaxy is subject to a gravitational pull toward its innermost regions. In this way, the hearts of all galaxies should be able to acquire huge masses of slowly infalling stars, gas, and dust, merging them into a tight swarm. If the current theory of stellar evolution



Within a few light-years of the Galaxy's center we see a white-hot region possibly due to the accretion disk of a giant black hole too small to be pictured. In any case, even artists have difficulty imagining such an enigmatic state of matter. Painting by Lola Chaisson.



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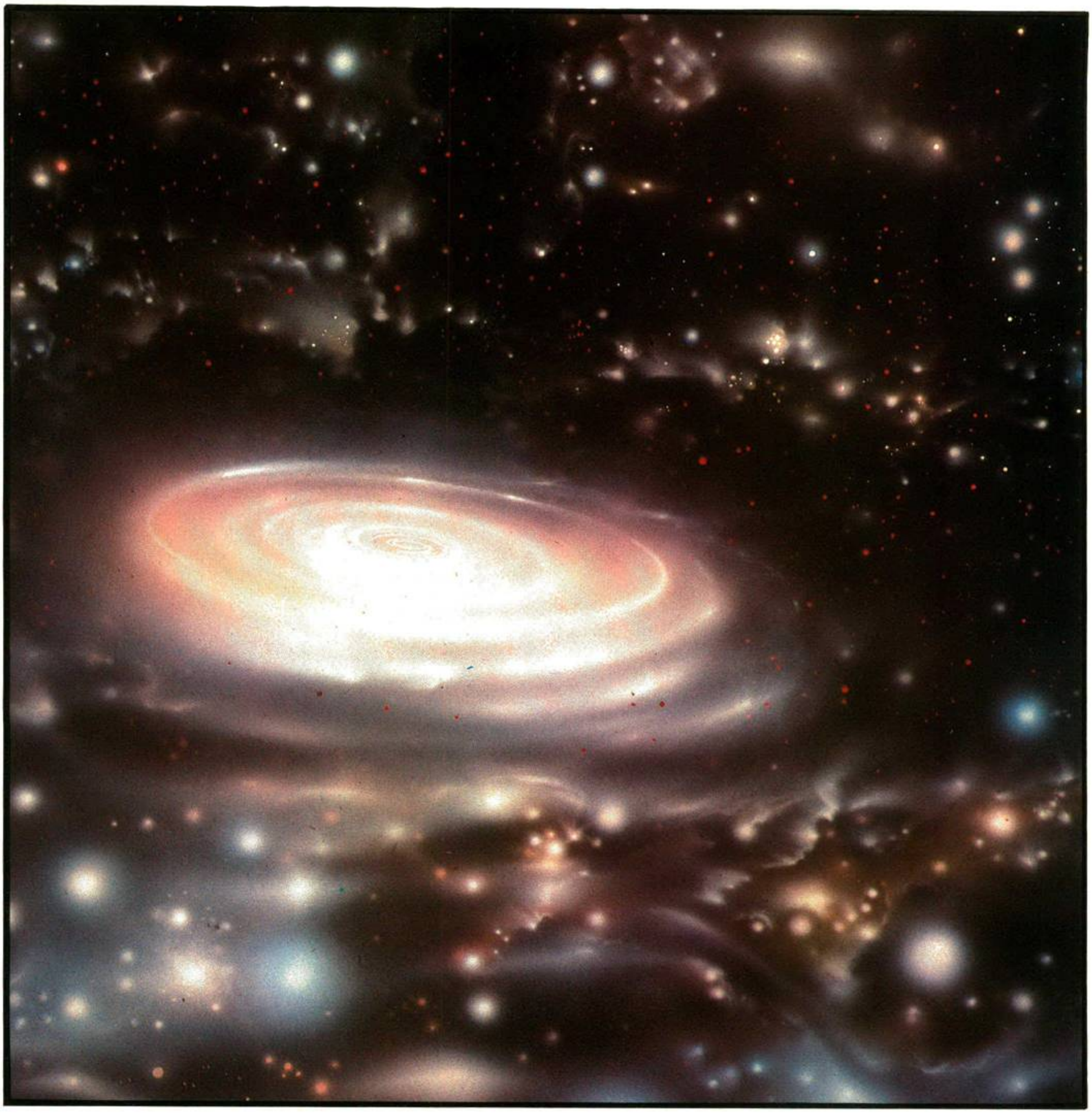

Sweeping in over the Three-kiloparsec arm, we see the intricate and complex structures lying at the Galaxy's heart. The scale of this image has been somewhat distorted to show more detail, and in reality the crowding of stars in the Galaxy's core would obscure our view of the center. Painting by Mark Paternostro.

is correct, then such a maelstrom may not be able to withstand ultimate collapse into a black hole.

So what's the bottom line? Is there a gigantic black hole at the nucleus of our Galaxy? No one knows for certain at this time. To be sure, several groups of researchers are continuing to examine, monitor, and model this fascinating, though mysterious, domain of our Galaxy. They've not yet forsaken studies of the galactic nucleus, though neither is the verdict yet delivered on its true nature.

If it seems that the current impression of our galactic center is open to debate, that's because it really is at present a most debatable subject. Astronomers are only now learning to grope in the dark. We are only beginning to decipher the clues contained within invisible radiation, to appreciate the full magnitude of this entirely novel realm deep in the heart of the Milky Way. That's why some of us maintain that our research should not yet even be called science. Rather, it's exploration — but absolutely fascinating exploration, enabling us to return from our telescopes with tales of the monuments at the core of the galactic park.

Eric Chaisson is an associate professor at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. At Harvard, he teaches a popular undergraduate course on "Cosmic Evolution," and is currently involved in the radio exploration of the galactic center. His wife, Lola Chaisson, a scientific illustrator, used an air brush to render the accompanying views of the Galaxy.

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Sperling's Eight-Second Law*

Everyone who sees a total solar eclipse remembers it forever. It overwhelms the senses, and the soul as well — the curdling doom of the onrushing umbra, the otherworldly pink prominences, the ethereal pearly corona. And incredibly soon, totality terminates.

Then it hits you: "It was supposed to last a few minutes — but that couldn't have been true. It only seemed to last eight seconds!"

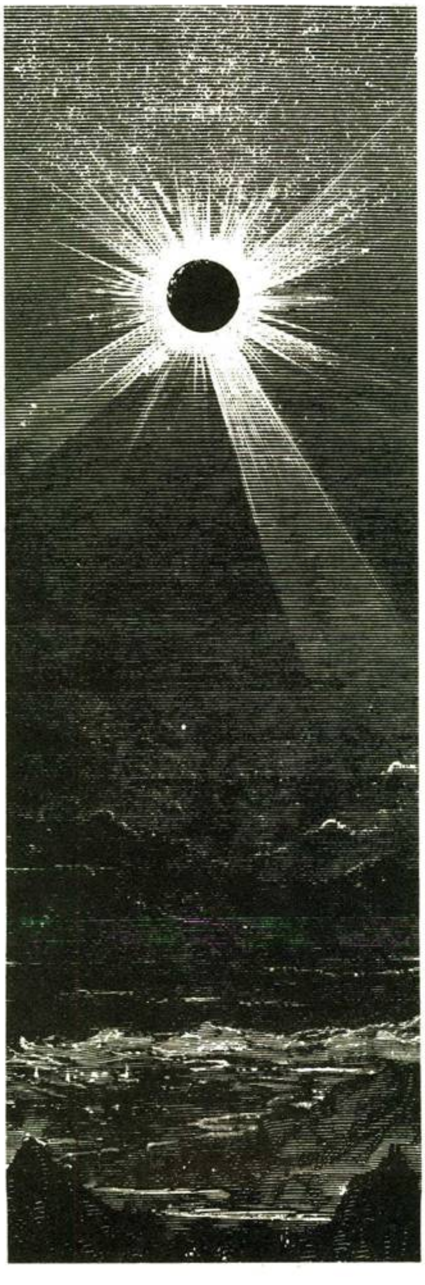
This effect frustrated my first four eclipses, and most fellow eclipse fanatics assure me they've been bothered by it, too. Yet tape recordings, movies, and the whole edifice of astronomy and celestial mechanics all claim that it *did* last the full, advertised, two to seven minutes — to within a few seconds, that's what *really* happened.

Where did all that precious time get lost?

Eclipse Watching

True eclipse freaks recognize only two modes of life: eclipse expeditions, and preparing for them. They'll devote a year or two to perfecting equipment: telescope, camera, weird filters, and film — sandproofed, soundproofed, rainproofed (heaven forbid!), and bug resistant. No matter what their expedition sees — or does — along the way, they'll fret about totality. Will * the * clouds * part? * Will * the * equipment * work? * WILL * WE * SEE * IT?

The partial eclipse is a tantalizing, exasperating hour and a half. Then the diamond ring forms, gleams, and vanishes, and at last they have totality. They gape in awe for just a second, then dive desperately into the sequence, many times rehearsed, of exposures, adjustments, notations so hurried they can only be unraveled from the tape recordings afterwards.



Inevitably, totality terminates too soon, often even before the planned sequence does, and they never make it to their own hard-won free-looking phase. "But I got it on film!" they proclaim, "and I can frame that and glow at it forever — even though I only saw it through the camera's finder."

The novice and the non-astrophotographer take the "hang-loose" approach. Restless in the partial phase, they get impatient and even quarrelsome around the one-hour mark. But in the last ten minutes they can feel it: totality's a-comin'. The world is darker, oranger; shadows look queerly sharp-edged. There's a nip in the air, the birds are atwitter, and shadow bands go skittering around. The ominous umbra sweeps in, the corona unfolds, the diamond glitters and is extinguished, and "OH * MY * GOD * THAT'S * THE * MOST * BEAUTIFUL * THING * I'VE * EVER * SEEN!" They stare transfixed, all their senses open, trying to take in as much as they can. Unwilling to concede that totality can't linger past third contact, they keep staring at the emerging solar sliver long after it gets painfully bright. Finally, they must be ordered to look away. Then, limp, with shit-eating grins, they applaud, or yelp, or shuffle aimlessly and ask where the next one's gonna be and how t' get there.

Both styles of eclipse-watching yield the viewer a solid eight seconds of memory.

Go ahead: replay your own.

See — *it's about eight seconds* long! I replayed all my images of my first four totalities in about half a minute. And that was after seeing twelve-and-a-half minutes of totalities. The other twelve minutes just weren't there! Poof!

---

*"All Total Solar Eclipses Last Eight Seconds"

Transfixed —

The culprit is attention span. If you stare transfixed, your mind, knowing the scene isn't changing, says "I already know that," and neglects to store away the same image yet again. So the solution is not to stare.

What? Not look at that most marvelous miracle you've traveled umpteen thousand kilometers to see?

No, I didn't say not to *look*, I said not to *stare*.

Pre-record a tape cassette, timed to start at the first diamond ring. On it, tell yourself what to notice during different parts of your precious few minutes in the Moon's shadow. Notice how the umbra envelops you, enjoy the diamond ring, then examine the prominences (they're bright so you don't have to be fully dark-adapted). Next, survey the corona — its general shape, and any outstanding features.

Switch away for a few seconds, to check the colors all 360° around the horizon. Since totality is just starting, it'll be darkest in the west, lighter in the east. Now, back to the Sun. Your eyes, now partly dark-adapted, are ready for the corona. Which is the very longest streamer, and how far out can you trace it? Where is the innermost dark wedge? Pick out an interesting pattern of filaments and make a mental engraving of it.

OK, back to the horizon. Sweep around again, and notice how much difference a minute or two makes. The west is lightening, foretelling totality's end, and the east is dark, where folks down-path are just now getting theirs.

Finally, back to the Sun. Review the most noteworthy coronal details. Look again at prominences, since there's a whole new crop of them on the 3rd-contact side. Watch for the pink fringe of chromosphere that anticipates — yes, here it comes — the second diamond ring.

How quickly the corona fades — and now even the last of it is going — and it's incredible how bright even that tiny wedge of Sun's surface can be!

And now this eclipse, too, is over — but this time you've won. From *each* separate span of attention during totality you can savor your eight seconds of mental replay. If you moved your attention enough times, you'll recall many times that eight-second limit. Yes, Sperling's Eight-Second Law can be beaten!

Norman Sperling
Somerville, MA

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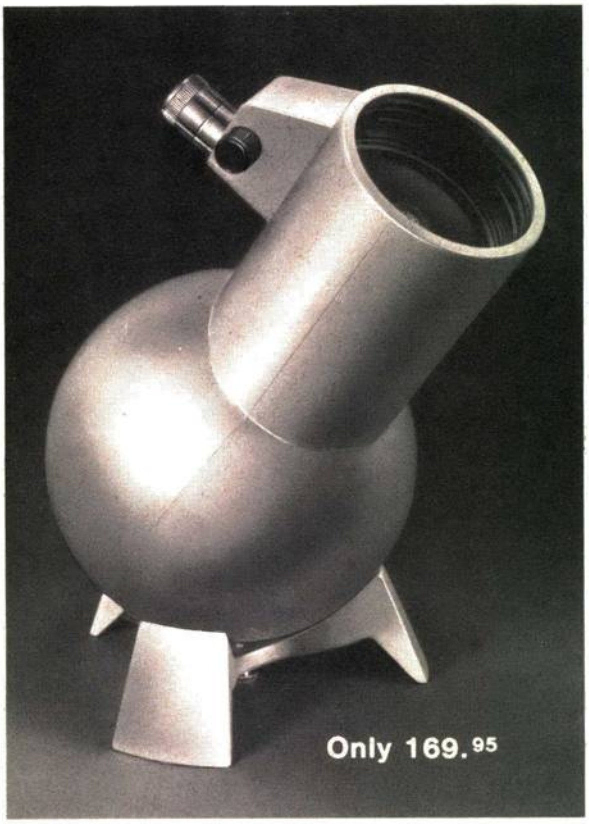

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Lunar Totality in the Land of the Sun

Before human beings blotted out the stars with artificial illumination and thought to "explain" natural phenomena with scientific language, a total lunar eclipse would have been viewed by multitudes, influenced many decisions, and possibly even changed a few lives. Nowadays, we don't count on the Moon for light; electricity has claimed our attention — evening's television and mornings off to work take up our time.

Nevertheless, like a perfectly timed machine, a total eclipse of the resplendent Moon put on quite a delightful sky show in the early morning of September 6, 1979, throughout most of the nation. It was a night of excitement, wonder, and natural beauty.

All photos by Richard Foltz

There was a full moon, of course, because in order for a total lunar eclipse to happen, the Moon must be directly opposite the Sun, with the Earth in between slowly cutting off the light of the Sun from the face of the Moon. Unlike total solar eclipses, which are rare and cover only small areas of the Earth, lunar eclipses occur fairly often over large areas.

Solar eclipses also involve the Moon, but there the Moon rolls into place, covering the Sun. A total solar eclipse is a spectacular sight, but it lasts a maximum of only seven minutes, and people chase all around the world at considerable expense to catch the infrequent occurrence, trying to observe shadow bands, Baily's beads, the diamond ring, the corona, the suddenly darkened sky and an awesome feeling of being no more than recorders of glories we don't understand.

In contrast, a total lunar eclipse can last an hour: plenty of time to get the cameras working properly, the telescope in place, time for note-taking, even taking time out for a smoke and missing at most a falling meteor. It's the difference between a drag race and a baseball game. Each has its own thrill and beauty, though one is over in a blink and the other unfolds in slow patterning.

We had seen the total eclipse of the Sun earlier that year in Oregon, a heart-stopping, eyeball-snapping spectacle. But we were up for this lunar show as well, with two pairs of binoculars, a 4½" reflector telescope, a 35 mm camera with tripod and time release cable, and no worries about weather as we'd had in Oregon. Escaping city lights, we left San Diego under cloudy skies around midnight, heading east on the interstate highway.

Driving out was itself a lovely overture to the main feature to come. Coastal clouds soon gave way to sky and full moon. Looking at the Moon was like examining a wrapped present — beautiful to look at outwardly, holding its mute surprise with a smile. And the highway took on its own lunar atmosphere, up and down through passes in massive mountain shapes, brightened to silver by the reflected gleam of the Moon. We practiced driving without lights on the empty freeway at about forty miles per hour and not only could we see clearly, but it felt like we were part of the night's celebration, going with the dark instead of cutting into it. The land had its own illumination, and we could easily follow the carvings through the hills that the highway made. White rocks lay like out-of-place snowballs.

We made the turn south to our observing site near Tierra del Sol, Land of the Sun, probably the smallest community in San Diego County. We could see mountains to the south rising out of low-lying, moon-illuminated clouds like islands in a sea; it gave us a sense of flying, of actually being up closer to the sky. We were experiencing a landscape out of a children's story, as if nature were choreographing her display, and this show was free for the looking.

We arrived shortly after 1:00 a.m. and set up the equipment on our concrete slab only a few hundred yards from Mexico. Overhead to the southwest, the Moon was beaming round as a sourball, drowning out the light of the stars, although Orion was steadfastly rising in the east, still lying on his side. The Moon was too bright to look at for very long, especially through the telescope. It lies, after all, in full bright sunlight out there in space.

Six or eight others from our astronomy association were also out, setting up scopes and cameras of varying ranges and sizes. We were quietly excited, passing the time by constant weaving between each other and our instruments and gazing upward. The only consistent sounds were faint night noises and the several electronic tones from a time radio cube tuned to WWV-10 from Ft. Collins, Colorado, which gives the atomically-precise time twenty-four hours a day, available for those who want to do timed-to-the-exact-second navigational or astronomical work. We enjoyed those faint background buzzings even though we were more amateurishly playful in our approach to the coming show.

At 1:20 a.m., the first phase of the eclipse began, but we could detect no changes until more than half an hour later, when we noticed a grazing shadow around 11 o'clock — if you make the face of the Moon a timepiece. A short while later, the *edge looked like a puff of smoke*, a light cloudiness like a paper about to burn. A quarter of an hour later, the

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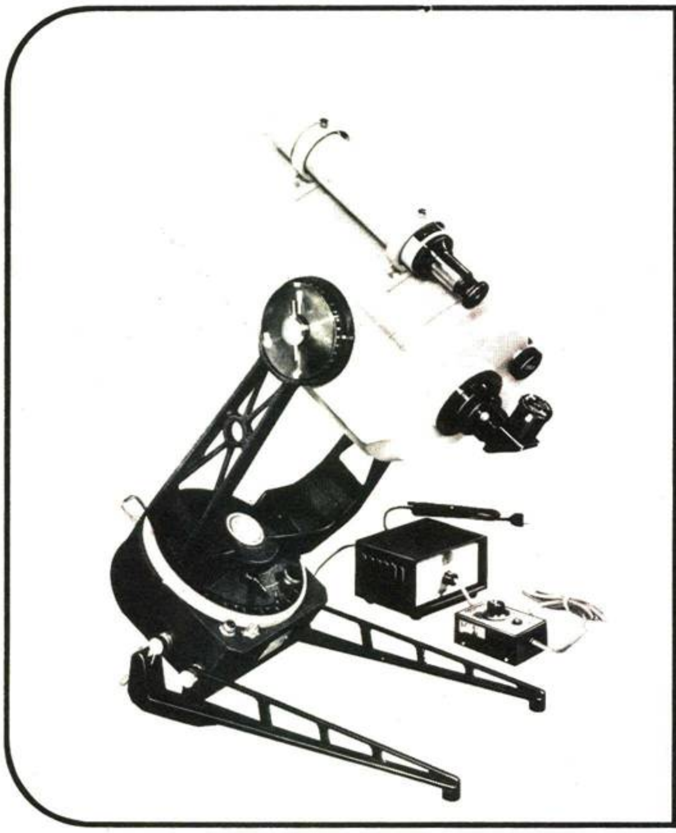

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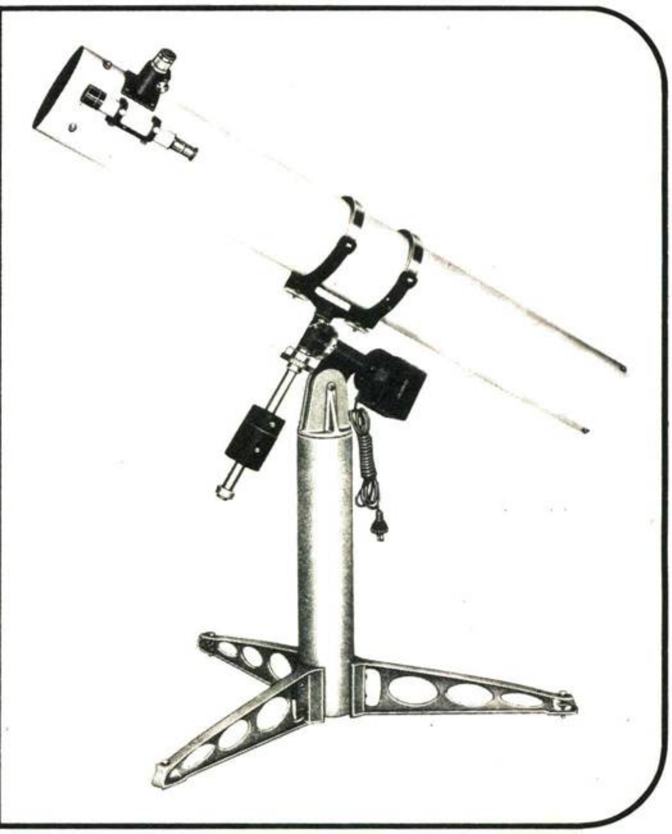

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Moon was definitely dimmer, a slightly off-center pumpkin, with a flattening dent in the upper left-hand forehead of the funny face.

The luminous feature of the lunar landscape was undergoing an inexorable transformation. By 2:30 a.m., the Moon had darkened so that we had to write notes by flashlight covered with red so as not to dull our retinas too much. Now there was a wide black scoop out of the top of the Moon. At 3:00, more than 50% of the Moon was in shadow, but we could still see the image of the darkened part. Colors began to show up boldly in the telescope, rust on the top edge of the dark part, then a lovely green-gray visible toward the lighter part. The sky was darkening noticeably and stars which had been invisible in the light of the full moon were now twinkling everywhere.

Time passed; cameras clicked or were held open in timed guided exposures; changes almost imperceptibly continued. Soon we could see with our naked eyes the rustiness of the eclipsed portion of the Moon, sitting like a hat, or drenching a portion of the Moon's face like soft rain. As the Moon dimmed, the velvet darkness of the sky sparkled with more and more stars; brighter and brighter glowed the awesome summertime Milky Way, veritable edge-on center of our spiral galaxy visible in Sagittarius, high over the ominous tail of Scorpius, as the mountains of Mexico were silhouetted against the stars. Through the telescope, the Moon was utterly fascinating, craters and mountains eerily illuminated and shadowed as the uncanny lights and hues passed over them.

With the Moon's light decreasing, we could also see it occult, or pass in front of, individual stars. Even a small crescent moon blots out most stars near itself, and such occultations are not visible except of the very brightest stars. Now, however, it was as though we were being treated to a number of small secrets: the Moon would first draw near dim stars and then blink them out as it passed in front of them. Then the stars would reappear at the other edge of the Moon some time later, highlighting the Moon's slow and majestic movement eastward on its course around the Earth, even as the Earth's rotation made it sink toward the west. One of the pleasures of a night of such viewing is that one begins to experience for oneself, to feel, to sense in one's feet, these ancient motions which shape our daily lives.

By 3:30 a.m., the eclipse was total, a condition which lasted forty-five minutes. Nothing sudden happened as it had in Oregon, when the sky had flip-flopped as the Moon ate the Sun. But gradually now, ever so slowly, while one sat out here in the warm desert night at 4000 feet and contemplated the now completely transformed Moon, viewing it through telescope or binoculars or simply unaided, one finally became aware, not in one's mind so much as in one's senses and veritable body, that something singular and striking had presented itself to us. For now, at last, the Moon was entirely rust-colored, a magnificent luminscent bronze red. And it glowed. It seemed to be lit from within; it was a bulb generating its own light instead of reflecting the bent and scattered leftover light of the Sun flicking past the edge of the Earth which was now settled squarely between Sun and Moon. And this glowing dark red-gold bulb was three-dimensional, rounded, not like a flat plate as the Moon usually appears, but truly spherical like a turned-on basketball. It was a small queer incandescent rust-colored ball in the vast orb of the now fully darkened sky scattered with millions of flickering lights — but not so small when one sensed the distances involved. And this magical egg was nesting in the midst of a gorgeous set of dim fourth and fifth magnitude stars: snuggling up quite close to some of them, stars to the limit of naked-eye visibility, stars glittering around the rim of the dusky Moon as it hovered in the faint constellation Aquarius.

It looked like some surreal science fiction painting. But it was real, breathtakingly so, and finally as lovely in its peculiar leisurely way as the total eclipse of the Sun, a slow silent stoned light show in space for anyone who would take the time to enjoy it. Although there was a whole sky full of stars to observe, we couldn't take our eyes off the Moon. It just sat up above us, moving slowly down to the west, glowing like a sorcerer's balloon, like a Christmas tree ornament, like a child's translucent marble.

Then totality was over and the top edge of the Moon began to brighten in white, and the fainter stars began to disappear as the Moon lit up again, and the Milky Way dimmed and the Moon got brighter still and we watched the whole process reverse itself.

It was time to go home to the sea and sleep. While we drove west, the magic continued as the rising orange-red Sun began to paint the sky soft orange in the east, baby blue directly in the west and little-girl pink above, startling colors; there opposite the Sun was the Moon now pale silver-orange where the blue heavens changed to pink. What a sky; one could hardly believe it still had anything left for us, but it did, prodigal sky, lovely vault. And the Moon filled the view like a bubble. It winked in and out of the mountains as we drove. The Moon knew, too, that the show had been a brilliant hit.

Our sleep was bewitched with *beauty.*

John and Stephanie Mood
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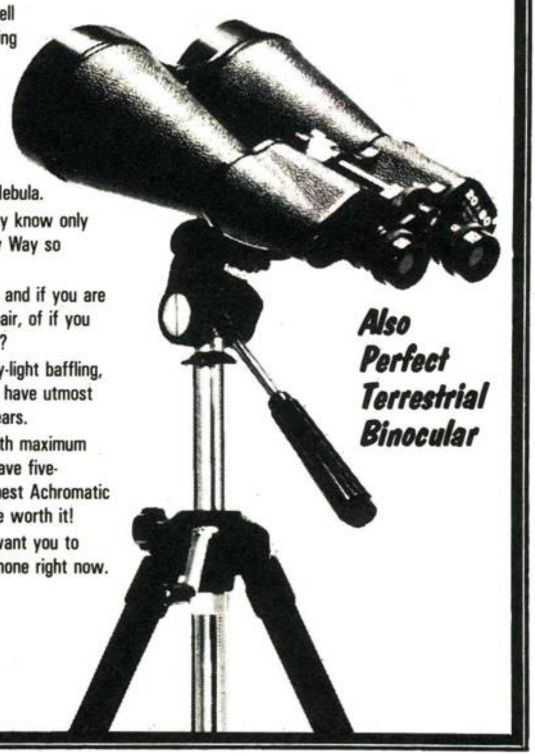

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eye
on the
sky

constellations of the milky way

the wanderers

At the beginning of August, the planetary arrangements seem much the same as those of last month, but the resemblance is only superficial. True, Mars, Jupiter and Saturn are still in the evening sky, while Mercury and Venus inhabit the morning skies, but during the course of August changes will happen: both Mercury and Jupiter will disappear into the Sun's glare and Saturn will nearly do so.

The array of planets in the evening sky shows Jupiter very low in the west and Saturn almost as low. **Jupiter** is the brighter of the two by far, but because you'll be viewing it through a lot of atmosphere, Jupiter will be only moderately easy to see (the remnants of twilight won't help either).

Jupiter lies in the constellation Leo, and is slowly moving eastward against the stars toward an even slower moving Saturn. Though Jupiter vanishes from view early in August, the date of conjunction (when the Sun actually overtakes it) doesn't come until September 13th.

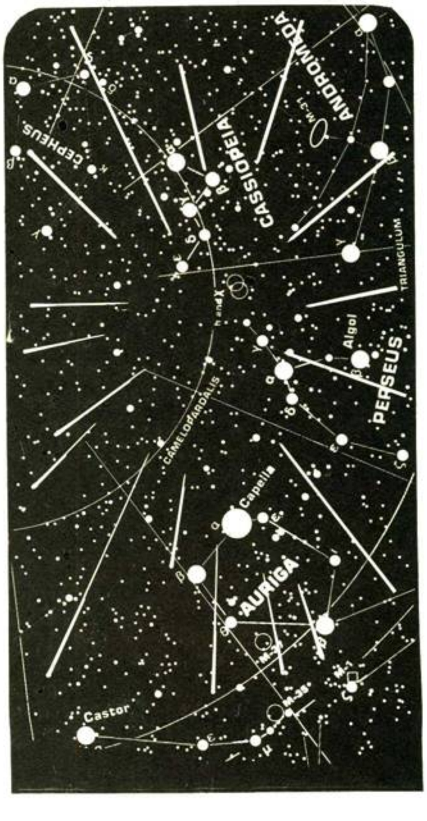
Saturn, near the Leo-Virgo border, is substantially dimmer than Jupiter. It sets about an hour and a half after the Sun does, and will become increasingly more difficult to find as the month progresses.

Saturn's conjunction with the Sun happens only 10 days after Jupiter's — on the 23rd of September. When the two emerge from the blaze of sunlight into the morning sky later this fall, you'll see the start of a triple conjunction between them similar to that of Mars and Jupiter during the first half of 1980.

Mars, the *third* naked-eye planet in the evening sky, lies in central and eastern Virgo (remember: on the sky, when you face south, east is to the left and west to the right). Slightly dimmer than Saturn, it'll be an orange dot low in the southwest that sets about 2 hours after sunset.

Shifting now to the morning sky, **Mercury** continues the apparition begun last month, with the date of its maximum elevation over the eastern horizon being the 3rd. Seldom outstanding, Mercury's brightness is about midway between that of Jupiter and Mars. This apparition of the planet isn't the best, but to get one better you'll have to wait until mid-November.

To locate Mercury, go outside about 45 minutes before sunrise and look east-northeast. The brightest stars you'll see there, fading in the growing twilight, are those of Orion, Canis Major and Minor, and Gemini. Mercury will be near Gemini's twin stars of Castor and Pollux. A line from Rigel to Betelgeuse (in Orion) extended about 1½ times will just point to Mercury.



Venus, of course, is easy to locate. Its great brilliance and early rising guarantee it a prominent position in the eastern morning sky. On August 24th, it'll be at greatest angular separation from the Sun (this is called elongation), a distance of 46°.

August is the month of the best-known of all the meteor showers, the **Perseids**. Reaching peak activity around the 12th of August, this shower usually gets mention even in the newspapers, and on radio and TV.

The shower is caused by the Earth intersecting the orbit of comet Swift-Tuttle. Strewn in the orbital wake of the comet are many, many small pieces of debris about as substantial as cigarette ash, but traveling at velocities relative to us of 60 kilometers per second. When these impact the atmosphere, they heat up, glow brightly, and rapidly burn out.

Since all these meteors travel nearly in the same stream, they appear to come from one small part of the sky (Perseus). Thus their apparent divergence out from a radiant point is only a perspective effect; their real paths lie parallel.

The time of greatest activity this year will be the night of the 11th/12th, peaking in the pre-dawn hours of the 12th. Meteors are almost always seen best between midnight and dawn for then you're on the "forward" hemisphere of Earth as it plows headlong into the meteor swarm. An additional plus this year will be the absence of the Moon: being barely past new phase, it'll set virtually with the Sun.

The number of meteors in the Perseid shower vary a bit, but the usual rate is something like one every minute or two. The numbers you see will dwindle if you: (1) live in a large

Vic Bilson, a reader in Wichita, Kansas, took this shot showing the Big Dipper rising in the northeast. With his camera tripod-mounted, he exposed Ektachrome 200 for 5 minutes with a 50 mm lens at f/1.4. Jupiter is the brightest streak in the picture, near the right-hand side.

city, (2) go outside from dusk until midnight only, (3) don't look at the Perseus-Cassiopeia region, or (4) all of the above! Give the skyshow an honest chance by trying to avoid these very common diminishing effects. (Camera buffs: take a look at this month's Photography in Astronomy.)

Another special event this month is a **solar eclipse** in the eastern Pacific and South America on August 10th. It's not a total solar eclipse, but an annular one. These occur when the Moon's apparent diameter isn't large enough to cover all of the Sun — a ring or *annulus* (hence the name) of Sun surrounds the black disk of the Moon. The southwestern parts of the U.S. will see a partial eclipse with the Sun appearing to have a "bite" out of it.

If you wish to view the partial eclipse, make a pinhole projector from a sheet of tinfoil taped over a 1" hole in stiff cardboard. (Use just the point of a needle to make a very small hole in the foil.) Hold the projector at right angles to the Sun so the pinhole casts a tiny image of it onto a sheet of white paper.

Two weeks after the eclipse, at full moon on the 25th, there's a very faint penumbral eclipse that'll probably pass unnoticed. During penumbral lunar eclipses, the Moon doesn't pass centrally through the Earth's shadow and so the amount of darkening is very slight. If any effect is noticeable, it'll take the form of a duskiness along the Moon's northern edge.

the starry sky

August evenings bring the Milky Way almost directly overhead, bisecting the sky like a huge glowing arch. The summer Milky Way is more brilliant than the winter, for at this time of year the night side of Earth is turned toward the center of our vast galactic home and we see the enormous clouds of stars surrounding us huddled more densely in that direction.

The core of the galaxy itself is invisible, of course, hidden from our view by the millions of stars and clouds of dust and gas in the spiral arms between us and the center. Astronomers, though, have recently developed techniques enabling us to probe the very heart of the galaxy (see this month's lead feature). Nevertheless, it is exciting to know that when you gaze at the Milky Way in Sagittarius, you are looking in the direction of the mysterious galactic core.

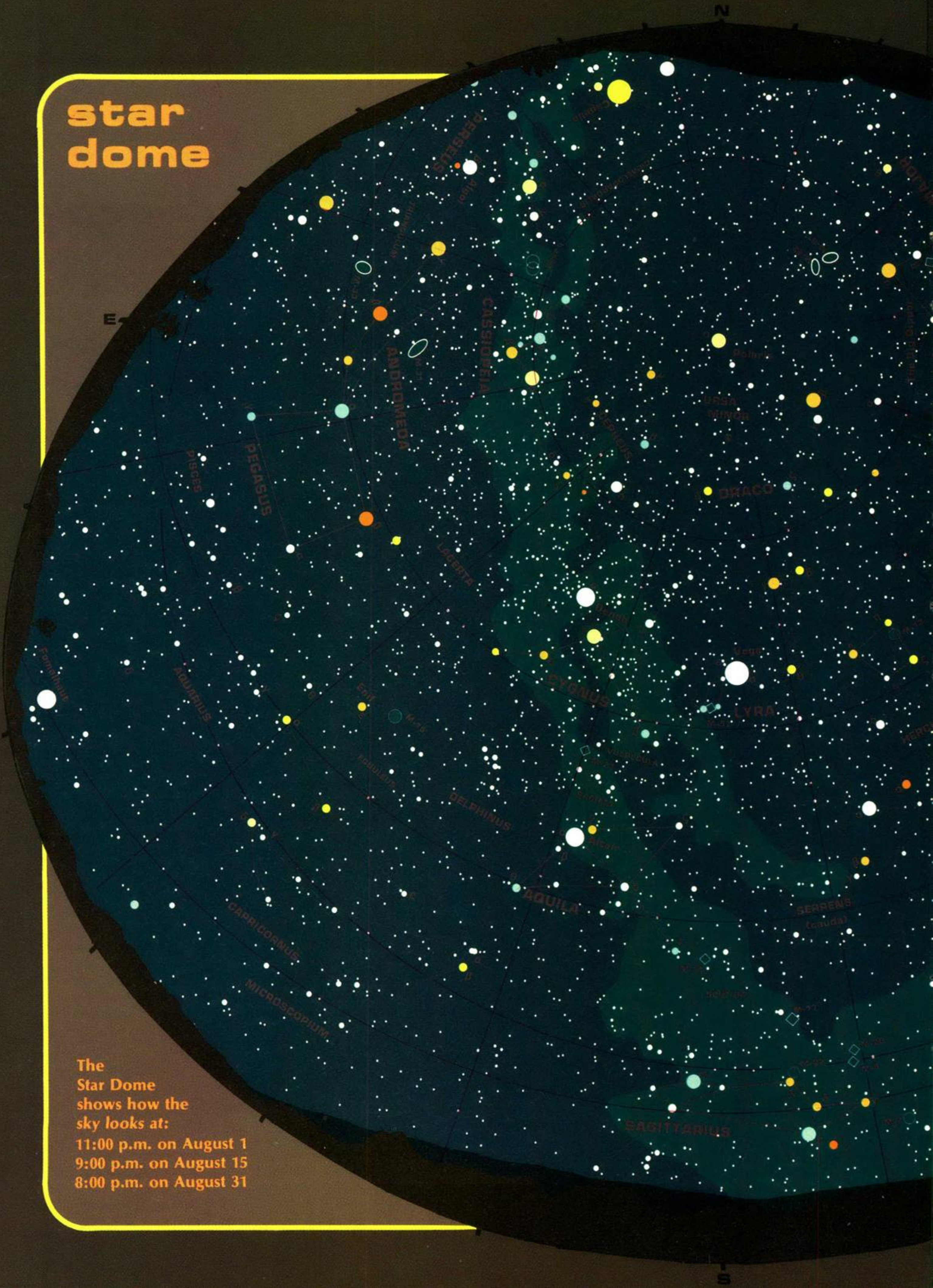
The southern constellations **Sagittarius** and its neighbor **Scorpius** ride low above the southern horizon, but are easy to identify because of their relatively bright stars and distinctive formations. Sagittarius is also known as the teapot because of its shape, which appears somewhat distorted on our Star Dome chart. You'll find it more regularly formed in the sky.

The brightest star in this part of the sky is ruddy **Antares**, found low in the southwest. Antares marks the heart of the scorpion, with its claws to the west (right) and its curving tail ending with the star **Shaula**, the "scorpion's sting."

The brilliant star sinking toward the western horizon on August evenings is **Arcturus**, the brightest star in the constellation Bootes. Look a little above Arcturus in the sky for the curving line of stars which forms the constellation **Corona Borealis**, the northern crown, with **Alphecca**, its brilliant "jewel" star.

Still higher in the sky, just to the west of the zenith, you should be able to pick out the **Keystone of Hercules**. If you're at a good dark-sky location

star dome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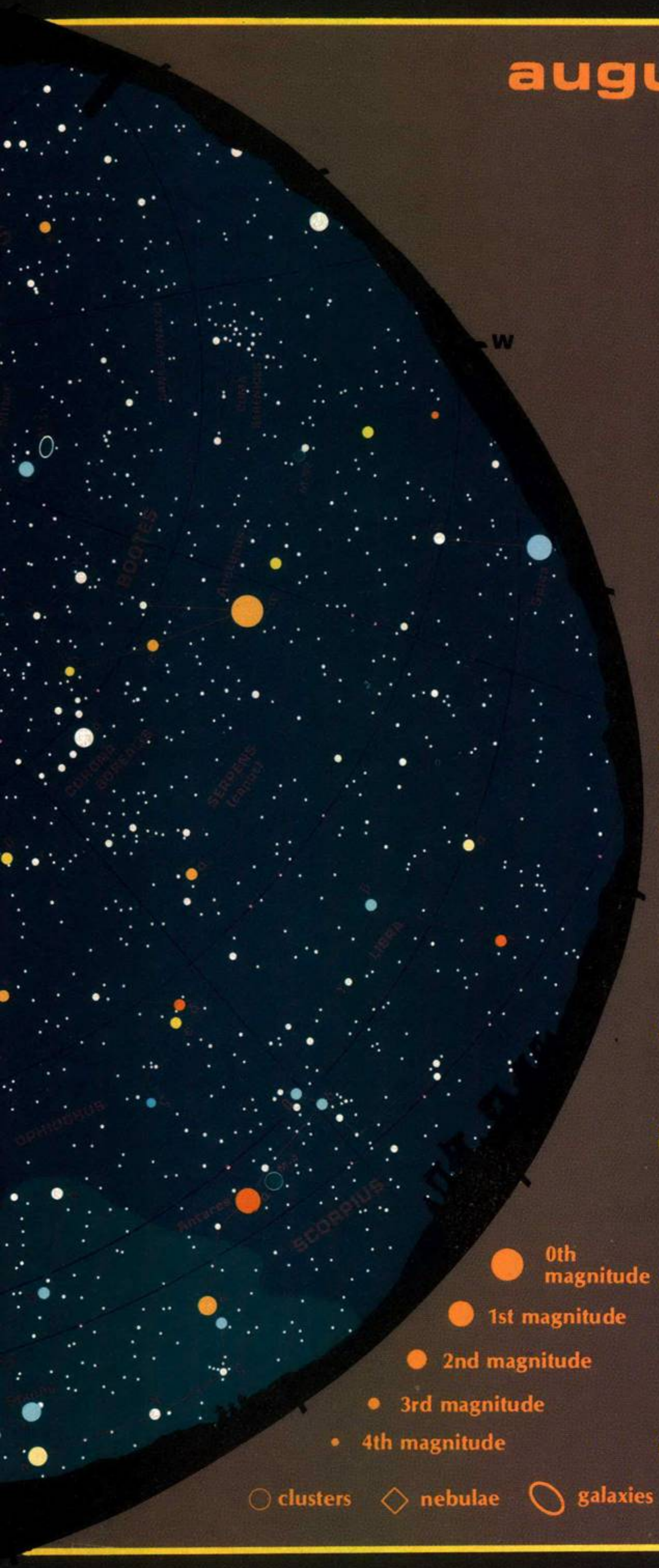
DRACO
Deneb
CYGNUS
Vega
LYRA
Fomalhaut
AQUARIUS
Enif
DELPHINUS
VULPECULA
Sagitta
Altair
AQUILA
SERPENS
(cauda)
Scutum
CAPRICORNUS
MICROSCOPIUM
SAGITTARIUS

The Star Dome shows how the *sky looks at:*
11:00 p.m. on August 1
9:00 p.m. on August 15
8:00 p.m. on August 31


W
BOOTES
Arcturus
CORONA BOREALIS
SERPENS (caput)
LIBRA
OPHIUCHUS
Antares
SCORPIUS
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

august sky almanac

3rd Last quarter moon (at 8:00 a.m. EDT): Moon rises around midnight and sets about noon. It'll be in the western sky after sunrise. Also, Mercury at greatest elevation in morning sky.

10th New moon today at 3:09 p.m. EDT. People in southwestern U.S. can see a partial solar eclipse.

11th Perseid meteors at their best tonight and early tomorrow morning.

12th By tonight, Jupiter will be impossible (or nearly so) to find.

15th Moon at apogee (farthest from Earth) this afternoon: 251,252 miles.

18th First quarter moon is at 6:28 p.m. EDT tonight.

24th Venus is at greatest western separation from the Sun (46°) today.

25th Full moon at 11:42 p.m. EDT tonight; faint penumbral lunar eclipse (see "the wanderers").

26th Mercury is in conjunction with the Sun, and (technically) moves into the evening sky.

27th Moon is at perigee (closest to Earth): 223,743 miles.

The silent shimmer of auroral drapes glows greenly in this photo by Doug Stewart of Ottawa, Ontario. The bull's-eye in the center of the photo is an optical effect caused by the pure monochromatic light of the aurora interfering in the film emulsion.

(such as out in the country on a particularly clear night), see if you can spot the globular cluster **M-13**, one-third of the way from Eta (η) to Zeta (ζ) in the Keystone. At about sixth magnitude, it should be just visible to the naked eye. Remember, that fuzzy dot you see is actually composed of hundreds of thousands of individual stars an immense distance away.

Directly overhead in August — appropriately enough — you'll see the stars of the **Summer Triangle**: **Deneb** to the east, **Vega** to the west, and **Altair** to the south. All three are bright white A-type stars, and each is the key to its own constellation — Vega the brightest star in **Lyra**, Altair in **Aquila**, and Deneb marking the top of the **Northern Cross**, actually **Cygnus** the swan.

Stretching down to the south from Deneb is the **Great Rift** of the Milky Way, in reality a vast cloud of obscuring dust between us and more distant stars. You'll need a particularly dark site to be able to trace out this feature, though. The North American Indians saw "Dark Constellations" in regions of the Milky Way like this. The Dark Constellations were forms defined by the absence of stars rather than their presence, a sort of negative view of the sky!

Above Deneb, look for the "house" shape of **Cepheus** on the edge of the Milky Way, outlined by five relatively dim stars. Farther north and rising higher in the sky as the night wears on, the constellation **Cassiopeia** is easy to pick out because of the distinctive "W" (or "M" if viewed upside down) pattern of its stars.

In the east, halfway up the sky to the zenith, look for the **Great Square of Pegasus**, the winged horse. Beginning with the highest star in the Great Square and proceeding clockwise, the names of these four stars are **Scheat**, **Markab**, **Algenib**, and **Alpheratz**. The ancient Babylonians saw in the Great Square a divine garden of paradise surrounded by four rivers, the abode of the god Marduk.

Trailing off to the northeast from Alpheratz are three stars marking the constellation **Andromeda**. Here, as in the case of M-13 in Hercules, good eyesight and a dark site will enable you to see a distant assembly of stars. But this time the assembly is far, far greater and much more distant — in fact, the most distant stars that can be seen with the naked eye. Beginning with Alpheratz, count from the Great Square to the third star. Now from this star look up at a right angle to the first three stars for two dimmer stars. The last of these two, which will look a bit fuzzy (if you can see it at all!) is not actually a star at all, but the Great Galaxy in Andromeda, known officially as **M-31**. (If you have trouble seeing it, try using a pair of binoculars or even opera glasses.) M-31 is another island universe like our own Galaxy, one of the nearest, and the only one (with the possible exception of M-33) visible with the naked eye.

Contemplating, with the knowledge of modern astronomy, this tiny dim speck of light seemingly floating just below the hazy glow of our own Galaxy brings the words of Boris Pasternak to mind:

And with an awful, dreadful list,
Toward other galaxies unknown,
Ponderously turns the Milky Way....

skylore

Birds, appropriately enough, are

well represented in the heavens. No less than seven constellations depict birds: Grus the crane, Corvus the crow, Aquila the eagle, Columba the dove, Pavo the peacock, Cygnus the swan, and Tucana the toucan. (A toucan? Yep, that's a bird all right — look it up!)

Of these aviary asterisms, two are especially prominent along the summer Milky Way — Aquila and Cygnus. Easily located with their distinctive forms, it is somewhat surprising that no particular myths are clearly associated with these constellations. Instead, they have each been connected to a number of disparate tales of rather uncertain form. Apparently the identification of the forms as those of an eagle and a swan came first, and then the attempt to locate them mythologically came later.

Aquila (as that king of birds, the eagle) is supposedly the only one to have gotten into the sky under his own power, the others having been placed there. In Greek mythology, Aquila is most clearly associated with Zeus, the king of the gods. Aquila assisted Zeus in his battles and was ever his obedient servant. One story has it that the eagle was sent on a mission to find another beautiful cupbearer for the gods, Zeus having become dissatisfied with Hebe's fumbling service (she was particularly noted for her ability to spill nectar on various gods at divine banquets).

Commissioned to bring back the most beautiful young thing he could find, Aquila flew down to Earth and soon spotted Ganymede, the son of the King of Troy. Snatching him up and bearing him back to Olympus, Aquila presented him to Zeus as the most perfect and beautiful living being in the world. Zeus, who like his ancient Greek worshippers was very open to any and all sexual possibilities, found himself quite taken by the youth and much in agreement with Aquila, and so Ganymede became the Cupbearer of the Gods.

Some versions of the story hold that Zeus himself flew down to Earth in the form of an eagle and picked up Ganymede himself. The constellation Aquarius has often been identified with Ganymede, placed in the sky by Zeus to get him out of the reach of his wife Hera, well-known for her jealousy. (Nor did it help matters that Hebe, whom Ganymede replaced, happened to be the daughter of Hera.)

Eagles may be rather royal figures, but swans seem particularly associated with death in mythology. This is probably due to their migratory behavior. At the height of the summer, swans take off for their breeding grounds in the arctic, trumpeting a characteristic call consisting of two notes. The ancients believed that the swans were singing a death song — as Pausanius wrote, "Swans sing before they die" — hence the term, *swan song*.

The constellation Cygnus the swan has been related to a number of mythic characters with the name "Cycnus" (the proper Greek spelling of *cygnus*), all rather tragic figures. Perhaps the one with the greatest astronomical relevance is Cycnus the half-brother of Phaethon, who was the son of the solar deity Helios (or sometimes Apollo — the Greeks never did straighten out all their gods and myths and make them consistent, which has been a source of scholarly — and not-so-scholarly — confusion ever since).

Phaethon was an arrogant and conceited youth, fond of boasting of his illustrious parentage to all and sundry. Naturally enough, claiming to be the offspring of the Sun more than invited ridicule, and so Phaethon, with the assistance of his mother, set off for the palace of the Sun to obtain proof that Helios was indeed his father.

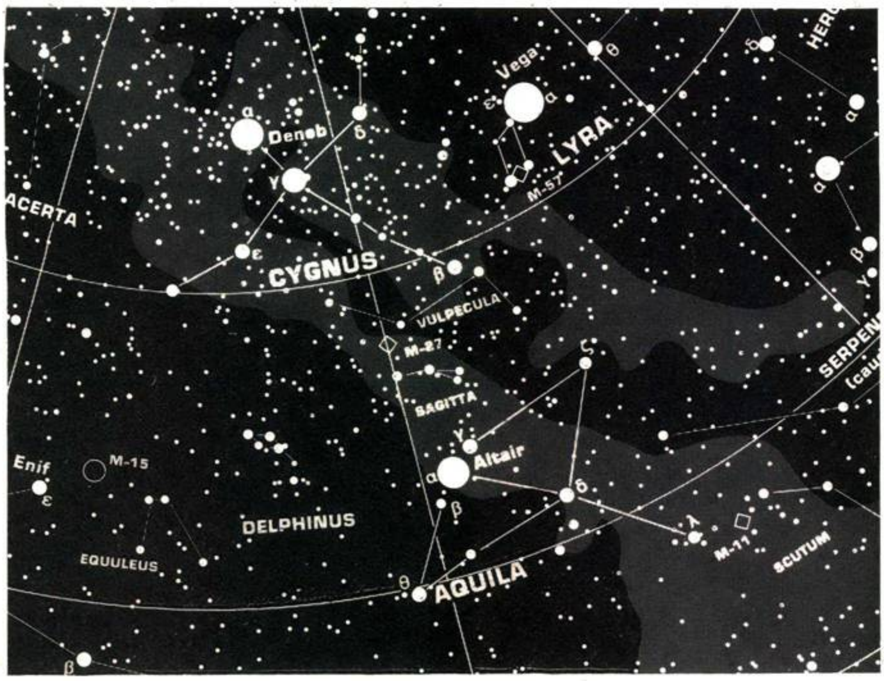
Helios was glad to see his son, and in a moment of rash paternal indulgence, promised to grant Phaethon anything he desired, swearing by the river Styx to make his oath inviolate. Phaethon then said that all he wanted was to borrow his father's neat high-powered chariot for a little spin around the world, to show off and impress his friends. (Of course, that particular vehicle just happened to be the Chariot of the Sun.) Despite all his father's warnings and pleadings, Phaethon refused to back down, so Helios reluctantly gave his son the keys to his chariot, making him promise to return it by sundown.

Of course, the fiery horses of the solar chariot proved too much for the boy to handle, and the Sun went out of control.

At this point in the myth the Greeks used the story to explain all sorts of things. Why is it that no trees grow on the tops of high mountains? Because the chariot of the Sun under Phaethon's driving swept down too close to the Earth and burned them all up. Why is the Sahara such a vast, dead desert? It was there that Phaethon came closest to crashing, and burned it dry. Where did the Milky Way come from? The poorly-guided chariot scraped against the vault of heaven, scorching and burning it. (Yes, this contradicts the story we related last month about Hercules and the goddess Hera's milk, but as we said above, the Greeks never did get all these things straight.)

Finally Zeus, alarmed at the disorder and fearing that the entire cosmos would be burned to a crisp by this pubescent delinquent, summarily ended Phaethon's joy-ride with one of his famous thunderbolts.

Phaethon's body fell into a river (either the Po, or the Eridanus, or the Padus, depending on whose version you read). His half-brother Cycnus dove repeatedly for the body so that Phaethon might be properly buried. Zeus, taking pity on Cycnus' fraternal devotion, rewarded him for his efforts by changing him into a swan (presumably making it much easier to dive into a river) and finally placing him in the heavens as the constellation Cygnus where he still flies along the heavenly river searching for his dead brother.



equipment
atlas

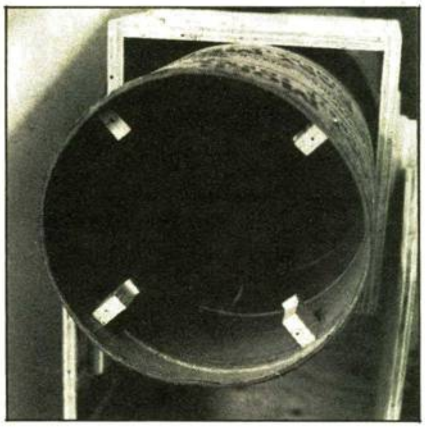
how to build a dobsonian telescope, part 3

by Bob Kestner and Richard Berry

You're now ready for the final step in building your 10" Dobsonian telescope, the optics and telescope tube. Optically most Dobsonians are Newtonian telescopes, that is, they use a parabolic mirror at the bottom end of the tube to focus light toward the top of the tube. A small mirror inside the tube, inclined at a 45° angle, reflects the image out the side of the tube to the eyepiece for viewing. With only three optical parts (i.e., two mirrors and an eyepiece), this design has long been the most practical and popular for home-built telescopes.

Hardware: to Make or to Buy?

You're now ready to decide whether to go the Dobsonian route, with simple and effective homemade mechanical components, or whether you'd like to buy commercially made parts. Three major items are necessary: a mirror cell, a secondary support, and an eyepiece holder. The requirements for mounting *precision* optical parts aren't as fearsome as many people think. All these parts really do is hold the optics, without warping or bending them, with provision for adjustment.



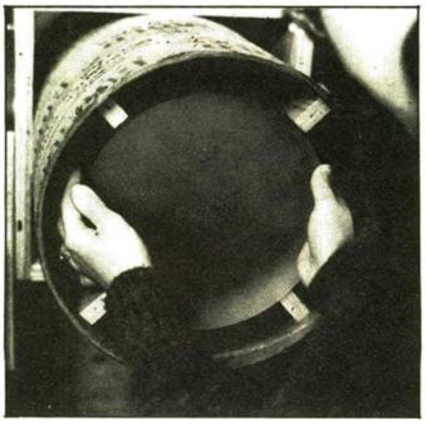
If you're thinking of eventually buying an equatorial mounting, or concerned about appearances, then you'll probably be happier buying parts. By going the Dobsonian route, you can probably keep the cost of your 10" telescope under $200, a real bargain in these days. Remember, too, that you can always retrofit your tube with commercial parts if the urge should strike, or when you've got some extra money in your pocket. Homemade components will, however, perform every bit as well.

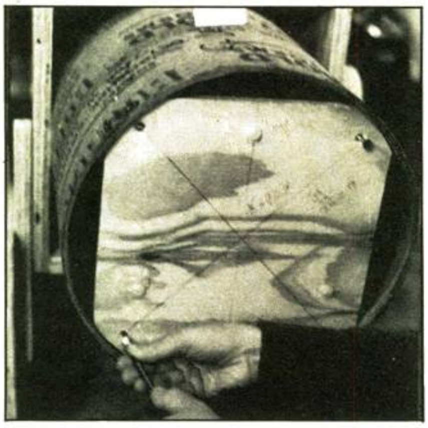
Making a Mirror Cell

The mirror cell supports the telescope mirror safely in its place at the bottom end of the tube. It has provision for tilting the mirror a little bit for accurate "squaring-on." (Cells, and other commercially made parts, can be purchased from the firms which advertise in ASTRONOMY.)

The Dobsonian approach is a very simple way to accomplish these goals. The mirror is held around the sides and in front by four small wooden blocks cut to fit it. The soft wood can't damage the glass. The back of the mirror rests against three bolts, which provide precise adjustment for the mirror, in a piece of plywood called the tailgate. The cell can be made in about an hour.

Saw four blocks from a piece of 1 x 2 pine wood about a foot long. Cut each block 1" longer than the thickness of the mirror — about 2½" for a typical mirror. Into each block, cut a notch ½" longer than the thickness of the mirror, and deep enough so that the block just fits between the mirror and the inside of the tube. For example, if the tube is 12" inside, and the mirror is exactly 10" diameter, then cut each block to a 1" thickness. Finish each block by trimming the overhang back to about ⅜" and sand the blocks smooth.



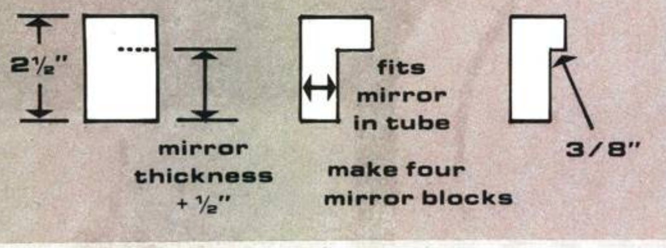


Next, cut a piece of ¾" plywood 10" square. Swing a compass from its center to mark the corners with a circle a little bigger than the inside diameter of the tube. Cut off the corners and file them down, a bit at a time, until the tailgate fits snugly inside the tube.

Drill three holes 7/64" in diameter on a 4" radius from the center, and thread each hole with a metal ¼"-20 bolt. If you can get ¼"-20 x 1¼" nylon bolts at your hardware store, thread them into the holes. The mirror will rest safely on their tips. (If you can't, use metal bolts, but be sure to round their ends with a fine file.)

Attach each of the four blocks 1" inside the end of the tube using a woodscrew from the outside. Test

Mirror Cell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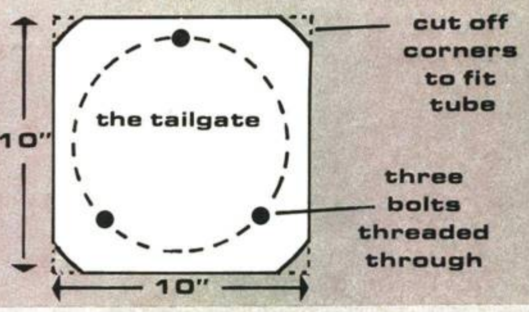
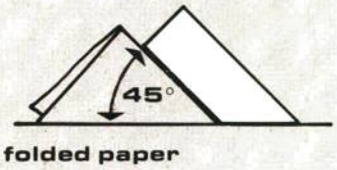
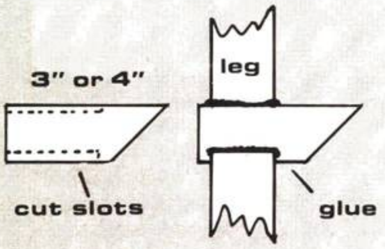
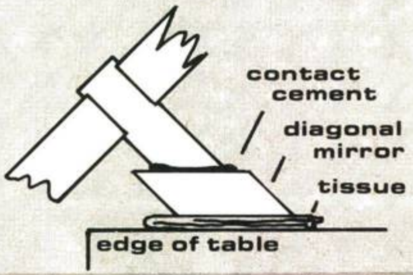
mirror thickness + ½"
fits mirror in tube
make four mirror blocks
3/8"


cut off corners to fit tube
10"
the tailgate
three bolts threaded through
10"

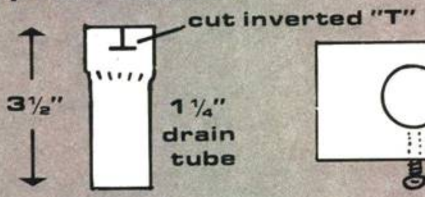
Diagonal Holder

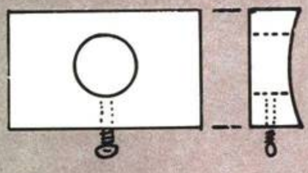

45°
folded paper

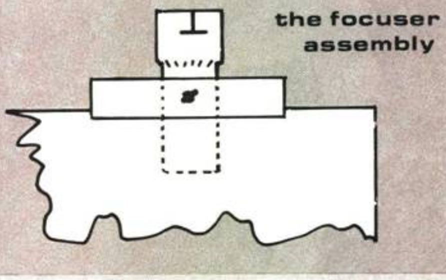

3" or 4"
cut slots
leg
glue


contact cement
diagonal mirror
tissue
edge of table

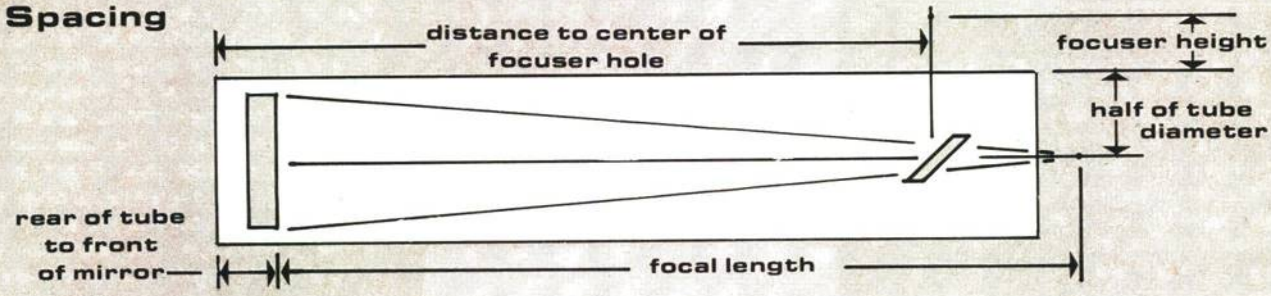
Eyepiece Holder


cut inverted "T"
3½"
1¼" drain tube



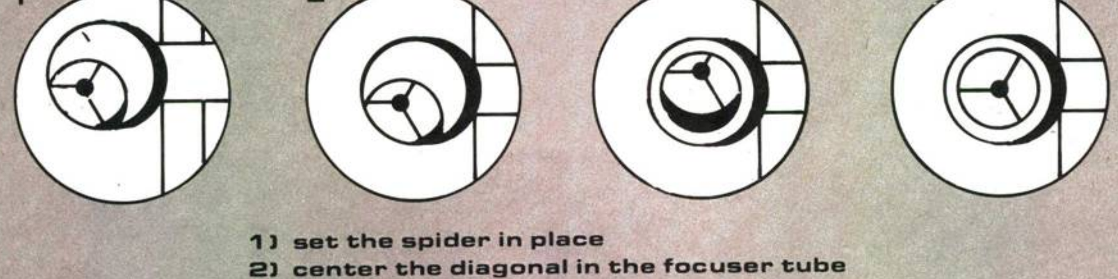

the focuser assembly

Spacing


distance to center of focuser hole
focuser height
half of tube diameter
rear of tube to front of mirror
focal length

distance to center of focuser hole = (focal length) - (focuser height) - (½") - (half of tube diameter) + (rear of tube to front of mirror)

Alignment

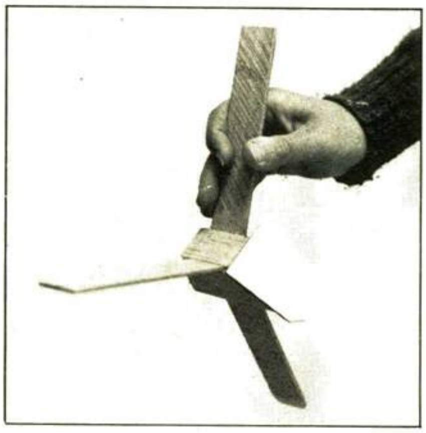


1) set the spider in place
2) center the diagonal in the focuser tube
3) center the mirror in the diagonal
4) center the diagonal mirror in the primary

whether the mirror fits between the blocks with about 1/32" to spare. If it doesn't, remove a little more from the wood blocks. Now put the tailgate in place, drill pilot holes, and run woodscrews into the four blocks from behind. The mirror is now safely and completely captive in its cell, though free enough to rattle just a little when you shake the tube.

The Diagonal and Spider

The spider is a three or four-legged gadget to hold the secondary mirror in the tube. It also provides adjustment for the secondary mirror. Commercial spider and diagonal holder units use thin metal vanes under tension for holding, and bolts and springs for adjustment. Instructions for installing them are usually included.

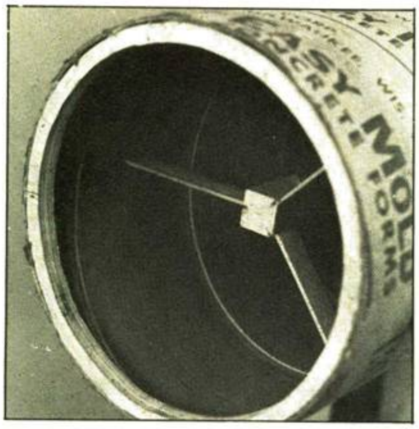


The Dobsonian spider and diagonal holder is made out of wood, and is so simple it can be made in about half an hour. Begin by cutting off a 3" section of 1" dowel rod, broomstick, or square stock as accurately as you can at a 45° angle. Sand the surface flat and correct any detectable error in the cutoff angle. (Use an old shop trick: fold a sheet of paper at one corner to make a precise 45° angle.) Using a saw or wood chisel, cut three grooves down its sides about ⅛" wide and 3/16" deep.

Now make three spider legs from pieces of wood about ⅛" thick and 1" wide. (Hardwoods such as oak work very well for this, but cedar shakes are the traditional Dobsonian spider legs.) Sand or file the ends to fit tightly into the grooves you cut in the diagonal holder block. Measure, mark, and cut off the spider legs for a tight fit inside the upper end of the tube. Once you have the fit right, glue the spider legs into the wood block.

Check once again that the spider can be inserted in the upper end of the tube and stay there held only by friction. If the fit is too tight, shorten one or more of the spider's legs slightly.

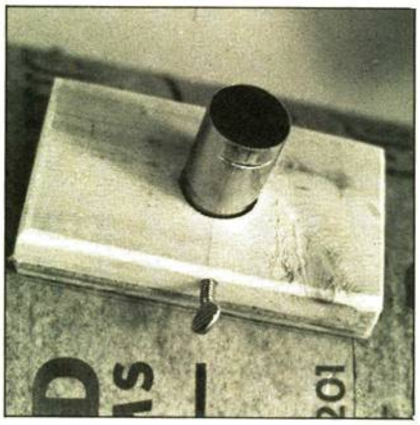
Next, glue the diagonal mirror to the wooden block. Contact adhesives, especially a smelly formulation called "Pliobond", work very well. Coat the 45° face of the dowel with the cement and let it dry completely (this seals the wood). Place the diagonal face down on a soft tissue. Coat its back with Pliobond. Also coat the 45° face of the dowel again. Allow both coats of glue to dry to tackiness (or according to directions on the tube), then press them together firmly. *Voila* — the diagonal is now mounted!



The Focuser

As with the other components, the focuser can be purchased or built by yourself. Snazzy rack and pinion widgetry may be appealing, but an adequate focuser can be made from a length of 1¼" chrome-plated brass drain extension (a plumbing component) available from plumbing and hardware stores and costing a little over a dollar. Take a standard 1¼" eyepiece to the store with you to doublecheck the fit.

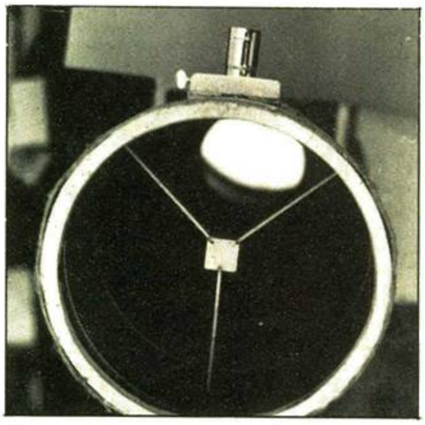
When you get the tube home, make two cuts in the shape of an inverted "T" and bend in the resulting flaps to hold an eyepiece securely. Cut the tube off about 3½" long.



Shape a block of soft wood about 3" x 5" to fit your telescope tube. In its center cut or drill a hole 1⅛" in diameter, then file it out until the drain part slides smoothly in and out through it. You can add a clamping bolt from the side, threaded through the wood, if you want to. You're now ready to assemble and align the optics in your telescope.

Assembly

Your next job is to figure out where to make the hole in the tube for the eyepiece holder. This is easy if you know the focal length of the mirror (it is usually scribed on the side of commercially made mirrors). Let's say, for example, that it's 56".



Measure the distance from the top of your focuser tube to the tube (say this is 2½"). Subtract ½" to allow for the distance the image lies inside the eyepiece tube. Add one half the diameter of the telescope tube to this (half of 12½" is 6¼", plus 2" equals 8¼"). Subtract this from 56" to find the distance from the focuser hole to the mirror surface, or 47¾". Measure the distance from the front surface of the mirror to the rear of the tube (say it's 3") and then add this to get 50¾". Measure this distance along the outside of the tube and mark the tube in the orientation you want for the eyepiece (straight out the side is conventional).

Cut a slot 1½" wide and about 3" long centered on your mark. Attach the eyepiece holder to the tube with wood screws. Slide and turn the diagonal and its holder in the tube until you can see the main mirror through the eyepiece holder. Now for the fine adjustments:

1) Hold your eye back about a foot behind the eyepiece tube and sight down it. Slide the spider and diagonal back and forth until the diagonal mirror is lined up with the eyepiece tube.

2) Rotate and tilt the spider and diagonal until the reflection of the main mirror is dead center in the diagonal mirror. Check that it's still in line.

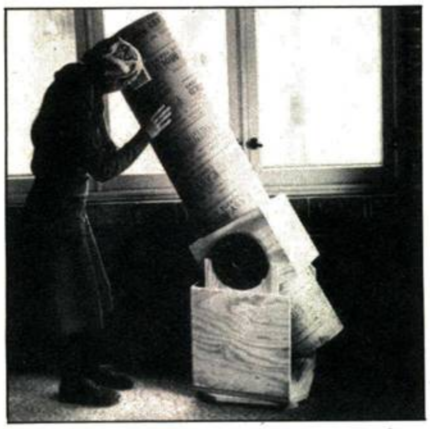
3) Using the bolts behind it, adjust the main mirror to center the reflection of the diagonal in the middle of the main mirror. You're now

in pretty good alignment — and the telescope is ready to test.

Take the telescope outside at dusk. Set up the mount, and with a low-power eyepiece in place, check that the tube is balanced. If it's not, slide the tube in the tube box a bit one way or the other. Note the smooth way the telescope glides from one position to another. (If it moves too easily, especially in the altitude motion, roughen the PVC plastic closet flanges with fine sandpaper.) Now point the telescope at a star, a planet or the Moon, and slide the focusing tube in or out to get the image sharp.

If you're lucky, sharp focus will be right in the middle of the range of travel of the focuser. If you can't slide it far enough one way or the other, move the whole eyepiece holder along the tube (that's why you cut a slot rather than a hole in the tube), realign the optics, and try again.

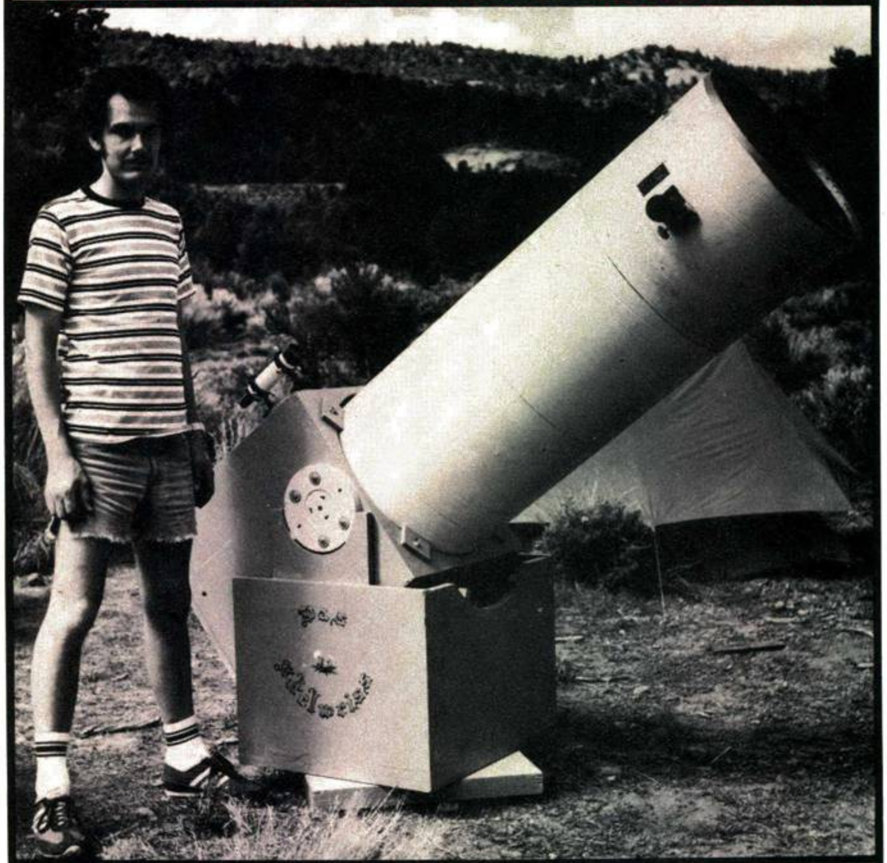
The images ought to be sharp and crisp. A little misalignment will give star images with a tail sticking out — you can cure this with a more careful alignment later, so don't let it worry you now. Look around the sky a while. Enjoy it. It's your telescope, and you built it.



This is the conclusion of a three part series on building an effective, low-cost, Dobsonian telescope. Part 1 appeared in the June issue and Part 2 in the July issue. The authors sincerely hope that the ideas, methods, and techniques presented in these articles will help people who never thought they could own a powerful telescope to enjoy the hobby of astronomy.

Bob Kestner is a long-time designer of Dobsonian telescopes, and is currently employed as a professional optician. In addition to helping many others in the San Francisco area build Dobsonians, he has completed an 18" of his own, and has written about Dobsonians in TELESCOPE MAKING #4 and #5.

a big telescope doesn't have to be expensive



You're in the mountains. You've pitched your tent and unloaded your telescope — perhaps a 10", but it could be a 12", a 14", or even a 16". Its portability still amazes you! As twilight turns into night, you marvel at the beauty of the pitch-black sky filled with stars.

You look up and spot Hercules rising high. "I'll look at M-13 first," you think. You grab the telescope and begin moving it. Right away you feel how smoothly a telescope can move. Without any fuss, you point the telescope in the right direction, centering the fuzzy ball of light on the crosshairs of the finder. You stand up to the eyepiece — which is always horizontal. "How convenient," you think. You give the telescope a little nudge, centering the cluster in the field. "It's really steady!" Next you focus. No shake.

And M-13: you can hardly believe it. The cluster almost fills the eyepiece field; you can resolve right across it with absolutely no effort whatsoever. You stare for a while, so excited you don't even notice your hand nudge the telescope, recentering the cluster in the field.

You think to yourself, "If this is 100x, what's 200x like?" In goes the high-power eyepiece. You focus and stare for a while. Another nudge to recenter the object. Then you realize that when you nudge the telescope, it moves into the center and then just sits there. No vibrations. No wiggling. No waiting for things to damp out. Then you think again, "How smoothly it moves!" Quickly you come to understand how simply the telescope operates without a clock drive — it just doesn't need one! After a couple of hours of observing, the nudging of the telescope becomes second nature. You don't realize you're doing it — even at high powers for observing the planets.

And the cost of the telescope? "It's a quarter what I could have paid for a smaller aperture," you think, "and I had the fun of building it myself!" As you find one object after another, and your familiarity with the sky grows, you gain confidence. "I know the sky. Who needs setting circles?" — and the large aperture pulls in the faint galaxies and nebulae so well you seldom miss finding one.

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how to find 'em even if you can't see 'em

by
Earle F. Dodds

On the "Messier Card" which comes with *Norton's Star Atlas*, Professor Owen Gingerich says: "...Most of the nebulae, clusters, and galaxies can easily be seen in a 3-inch refractor, and many of the brighter ones in binoculars. With 6-inch reflectors, quite a few amateurs have managed to find every object in the Messier catalog...."

Again, on the dust jacket of *The Messier Album* he says "...Nowadays it is easy to repeat Messier's observations...Today's amateur astronomer with access to a 6-inch reflector and reasonably clear skies can expect to track down even the faintest Messier galaxies and globular clusters...."

But, doggone it, for a number of inescapable reasons I'm locked in to doing almost all of my observing from my backyard. I can't escape light pollution, low-hanging smoke from my neighbors' wood-burning stoves, particulate air pollution from half a dozen not-very-distant industrial plants, etc. I seldom have a "reasonably clear, dark sky," even when the Moon is down. These problems have crowded me into a position of pushing my eye and my backyard telescope as far as I can in hunting for deep-sky objects.

But if these objects are hard-to-see, I can seldom tell whether they're in the field of view or not, and even if I assume they are, where do I start looking? You can spend an awful lot of time scrutinizing 0.8 square degree of sky and if you have to give up, you're still not sure whether the object was just too faint to see or was just barely outside the area.

Later on, I'll mention some ideas I've got on how to handle this problem, but to start with, let's take a look at four ways of getting some sought-after celestial object into your field of view.

Aiming

The simplest method, which works only with prominent, easy-to-see objects (the Moon, naked-eye planets, etc.), is to just point the tube at it, somewhat as though you were aiming a cannon. If you have a reasonably wide-angled finder scope, 5° say, you can ordinarily maneuver the object into the finder's field-of-view pretty easily — unless it's overhead or nearly so.

Star-hopping

A second method is to "star-hop" your way to the object. You do this by starting off at some bright star and, with the help of a star atlas, working your way along a chain of overlapping fields of view to the item you want. It sounds complicated, but a little experience will soon turn this method into the "old reliable."

To begin, you'll need a star atlas: *Norton's* and the Skalnate Pleso *Atlas of the Heavens* are both good. Both atlases go down faint enough to give a number of routes to star-hop along. (By the way, when you start out, pick routes to your objects where the stars lie about half a finder-field apart. Later, with practice, you can extend the distances to nearly a full finder-field.)

You also need your finder scope aligned parallel with the main scope; do this by centering a moderately bright star in the field of your eyepiece and then centering the same star in the finder's crosshairs. When you finish, check the eyepiece to see that the star hasn't wandered away. You cannot be too careful here: get that alignment perfect and locked into place.

To check out the system, let's try hopping from Caph (Beta [β] Cassiopeiae) over to M-52. First off, center Caph in the finder's field of view by aiming the scope at it, cannonlike. About 1½° south and east of Caph lies a close double star, Σ3062. The component stars are of magnitudes 6 and 7 and are about a second of arc apart.

Hop from Caph over to Σ3062. Just bring the double to the center of the finder's field of view (Caph will still be seen in the finder). 2° south and east of Σ 3062 you'll see another star of about magnitude 5 with a fairly close companion. This is Rho (ρ) Cas; center it.

By now, Caph will probably be out of the field, but two more stars will have appeared. One of these is Sigma (σ), a double star with 6th and 8th magnitude components 2° south and west from Rho. (Halfway between Rho and Sigma lies NGC-7789, a rich galactic cluster thrown in as a bonus.)

A degree and a half to the northeast of Rho is the 5th magnitude star Tau (τ) Cas. Hop over to it. Directly to the east of Tau, 2½° away, is a 5th magnitude star both double and variable. As a double, it's called OΣ496; as a variable, AR Cas. Center this star.

Keeping this variable double on the north/south crosshair of the finder, shift the field of view north a couple of degrees. A fifth magnitude star will slide into view near the north edge of the viewing field, a little to the east of the crosshair. This is 4 Cas.

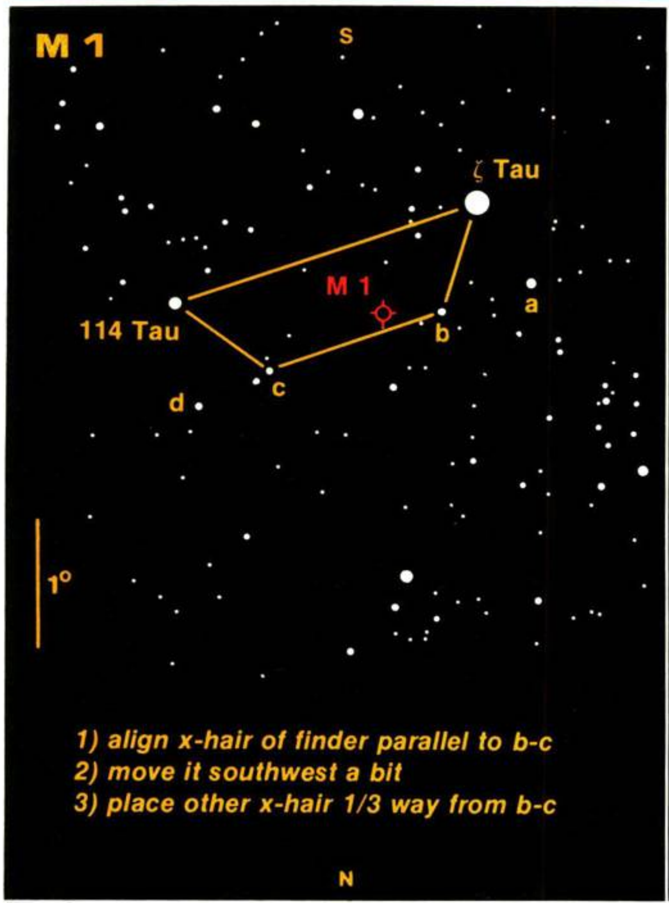
When it is well within the field, stop shifting northward and begin moving eastward. A shift of about a degree will bring into view a pair of stars at the southeast edge of the field of view. One will be 5th magnitude, the other about 6th; the brighter one is 1 Cas, the dimmer 2 Cas. The pair of 1 and 2 Cas, together with 4 Cas and AR Cas, make a rough equilateral triangle surrounding M-52.

Sweeping

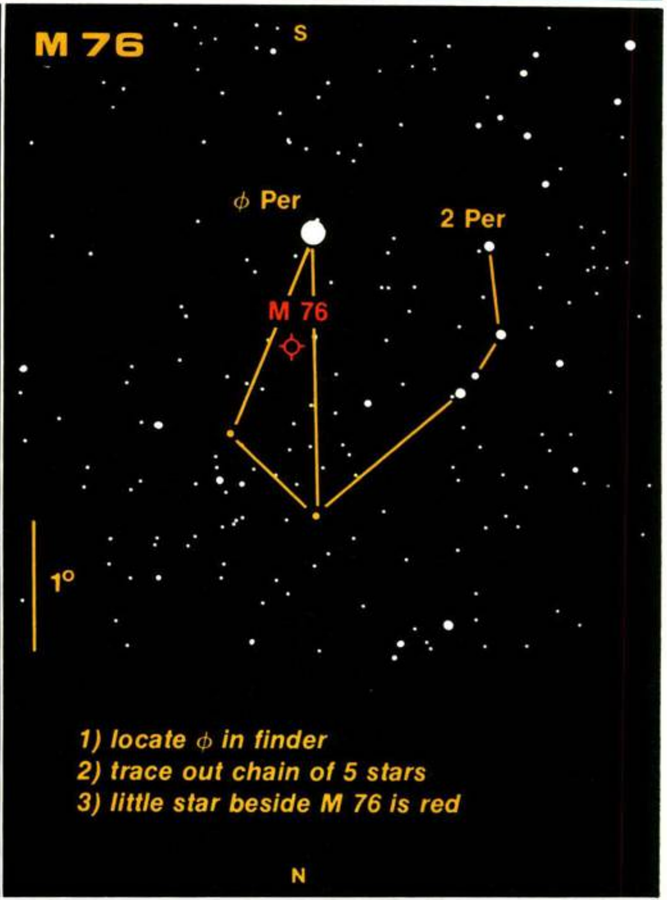
Method 3 also requires a good star atlas and "start-off" star. Here's how it works:

Suppose you're looking for M-1, the Crab Nebula. The Crab and Meissa (Lambda [λ] Orionis), the star marking Orion's head, have nearly the same right ascension. Get Meissa into the finder's field of view by aiming and then clamp the polar axis so the scope

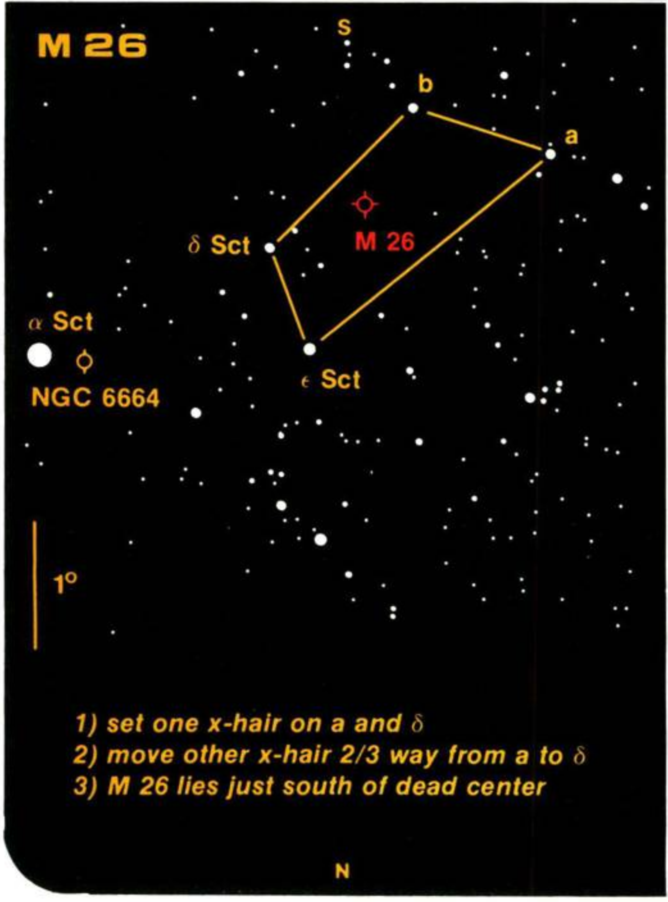
boxing them in


M 1
S
ζ Tau
114 Tau
M 1
a
b
c
d
1°
N

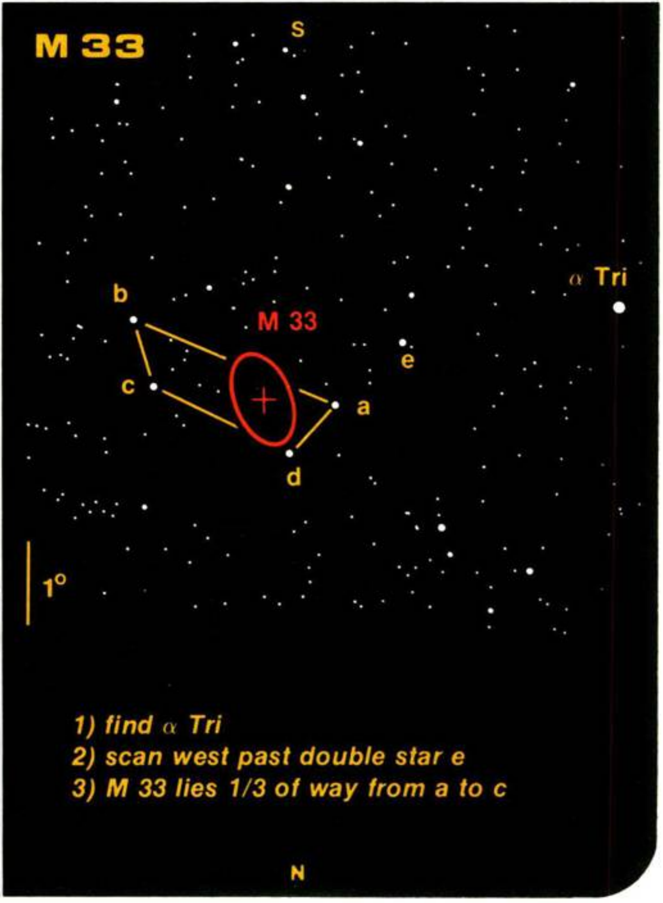
1) align x-hair of finder parallel to b-c
2) move it southwest a bit
3) place other x-hair 1/3 way from b-c


M 76
S
φ Per
2 Per
M 76
1°
N

1) locate φ in finder
2) trace out chain of 5 stars
3) little star beside M 76 is red


M 26
S
b
a
δ Sct
M 26
α Sct
NGC 6664
ε Sct
1°
N

1) set one x-hair on a and δ
2) move other x-hair 2/3 way from a to δ
3) M 26 lies just south of dead center


M 33
S
α Tri
b
M 33
e
c
a
d
1°
N

1) find α Tri
2) scan west past double star e
3) M 33 lies 1/3 of way from a to c

can't rotate in R.A. Sweep northward 12° and M-1 will slide into view.

Sounds easy, but the problem comes in knowing just how far 12° is; Zeta (ζ) Tauri is about 11° north of Meissa and a degree east of it. If your finder crosshairs are rotated so that one lies east/west and the other north/south, bring Zeta into view (it's a bright star — easy to spot) and place it on the e/w crosshair. M-1 is as far north of the crosshair intersection as Zeta is east of it. Move the hairs slightly to center M-1 (which will be invisible in your finder). Peek into the eyepiece and it should be there — unless it's a hazy night.

Setting Circles

The fourth method is the one all beginners want to start in on — and perhaps the last one they should be exposed to! Circles are wonderful things when made and used properly (in fact, I use them almost exclusively), but they're no substitute for knowing the sky.

Using them goes like this: once more you begin with a "start-off" star having known coordinates. Subtract the coordinates of the place you want to end up in from those of your starting point and you'll know how far to offset the telescope in both axes (R.A. and Dec.). Let's hunt up Uranus using this method and see how it works in practice.

Uranus is currently in Libra, so the logical starting point is Alpha (α) Librae, known as Zuben-el-genubi. Look up and copy the coordinates of the star (in the *Observer's Handbook*, say) and those of the planet in Planet Finder.

Turning on the drive, loosen the mounting's clamps in both R.A. and Dec. and swing your scope to center the star in the eyepiece. Retighten the clamps. Your telescope is now set and driving on Zuben-el-genubi. Adjust your setting circles so that they indicate the same coordinates as the star has.

You next unclamp one of the axes (either R.A. or Dec. — it doesn't matter) and move the telescope to Uranus' position in that coordinate. Reclamp the axis. Having unclamped the other axis, move the scope slowly until it reads correctly for Uranus. The planet should be visible in the finder — it's only 6th magnitude, after all. Center it in the finder and take a look in the eyepiece. Uranus will have a greenish-grey disk and look decidedly nonstellar.

How to Find What You Can't See

Sometimes you know just where to look with the finder, but suspect the object is going to be difficult — or even impossible — with the scope's main optics. What happens then? How do you decide whether you bungled finding it or it just wasn't to be seen that night?

To settle this I have developed a method I call "bracketing." Let's take our former example, M-1, and see how the system works.

The field of my finder is about 5° — I can just get both "pointer stars" of the Dipper in it. So, on my star chart or a photocopy of it (I use the Skalnate Pleso charts), I draw a 5° circle centered on M-1, using green ink because it shows up well under a red light bulb.

This circle indicates the area I can see in the finder when the crosshairs are centered on M-1. The most prominent object within this circle is Zeta Tauri, and the next most prominent star is 114 Tauri. About 1° north and west of the line joining Zeta and 114 is a chain of four stars of 6.5 to 7.5 magnitude, none of which is identified on the chart. This chain is a little longer than the distance between Zeta and 114.

Starting with the westernmost star in the chain, label the stars respectively (a, b, c, and d). All six of the stars will be readily visible in the finder scope. Now using stars Zeta, 114, b, and c, form a trapezoid and ink it in on the chart. This trapezoid "brackets" M-1. In effect, you've built a fence around M-1 and there's no point in searching for it outside of its pen.

Although you can work at the telescope with the atlas chart, I don't like to because it is too big and too white. I use George Kepple's *Astro Cards* in the observatory. Their scale usually is bigger than the atlas chart scale, and the cards show stars down to magnitudes 10 or 11. Ink in the bracketing trapezoid on the cards. So far, all this mapping work has been done inside — "desk" astronomy. Now you are set to go into observational astronomy.

The coordinates of Zeta Tau are 5^h34^m and +21°. Slew the telescope around until you have Zeta in the center of the field of view of both finder and eyepiece. Clamp up both motions and slip-turn the R.A. circle until it reads 5^h34^m. Check the declination circle to be sure it reads 21°. If it doesn't, reset the index so that it does. Now, loosen the clamps on both axes and turn to the coordinates of M-1 — 5^h32^m+22°.

Look in the finder. You won't, of course, be able to see M-1 even if you are dead on, but you should be able to easily see Zeta, 114, and the a-b-c-d chain. Compare the card or chart with what you see in the finder. You will have to turn them upside down because the finder will invert the image. (And if your finder has a right-angled eyepiece holder, as mine does, you will also have to turn the card over and shine a light through it because the prism reverses the image.)

M-1 is about 1/8 the width of the trapezoid from line b-c toward line Zeta-114, and it is about 1/3 the distance b-c from star b.

Rotate the finder eyepiece in its holder until one crosshair is parallel to line b-c, and then, with the slow motion controls on both axes, move the field of view around until you get the same crosshair picture in the eyepiece that you have on the chart.

When the two pictures correspond you will have the finder crosshairs centered in M-1 — whether you can see it or not. It just has to be there, so look into the eyepiece. You won't see any of the stars in your bracketing diagram because the closest one to M-1 — star b — is over a half a degree away.

There've been times (plenty of them, darn it) when the sky was so bad I just could not see anything there, but at least I didn't have to search around in the field of view to find it. I could either see it or I couldn't, and that was that.

This is just one of the hard-to-see objects I have worked out bracketing diagrams for. Even when the skies are good and I can see it at first look-see through the eyepiece, I always take a gander in the finder eyepiece to keep myself familiar with the bracketing diagram.

Fortunately, most of the difficult M-objects can be bracketed, and this technique gives any observer confined to his own backyard, with the attendant poor seeing conditions, a big leverage.

It's no waste of time to try to see something you know you are looking at, but it is a waste of time, and a frustration, to spend precious observing hours trying to see something when you're not even looking in the right place.

Why bother at all? Well, spending your efforts looking at easy-to-see objects may be very pleasurable, but it doesn't do a darn thing to sharpen observing skills.

You'll find some M-objects cannot be bracketed in a 5° finder field, but several of these (M-2 for instance) are so bright it makes no difference. I'm currently working up a list of M-objects which can be, and need to be, bracketed if backyard observers with 6-inch reflectors (like me) are to find them. It'll be a sizable list. But say, for that matter, why stop at the M-objects? The NGC is just loaded with items....

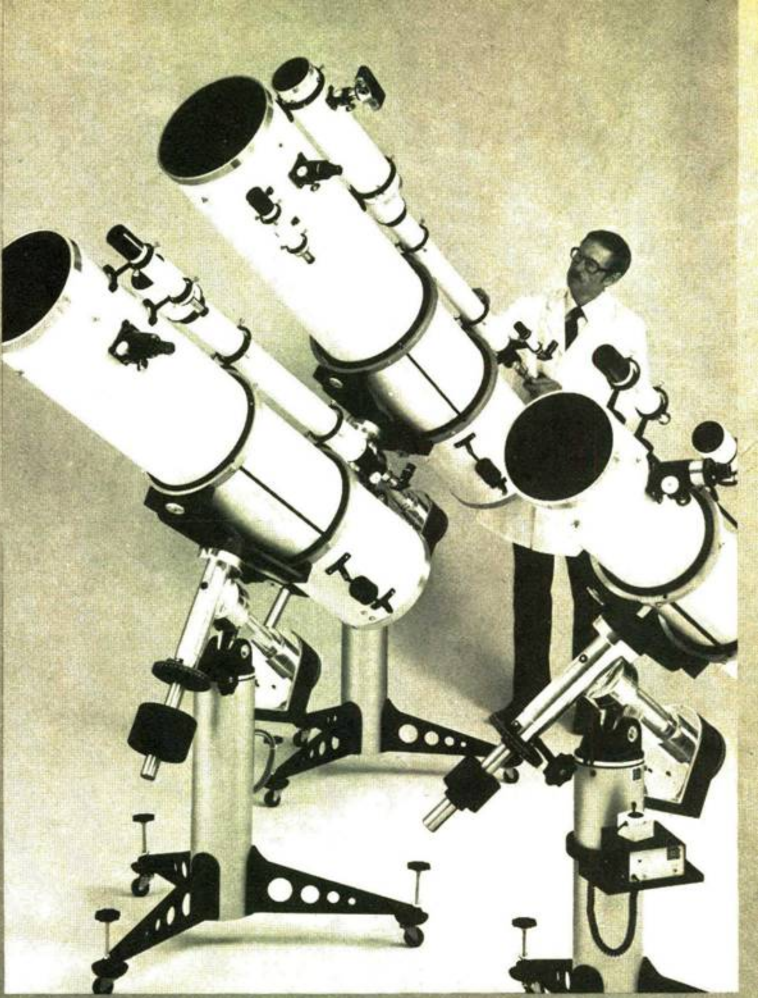
Earle F. Dodds' earliest astronomical observation was of Halley's Comet. He made his first telescope in 1926 and his design for a "simple, low-cost mounting" appeared in the January 1979 ASTRONOMY.

Meade precision photo-visual reflecting telescope systems

Large-aperture, high-resolution optics from the world's largest manufacturer of reflecting telescopes for the serious amateur.

Meade 6″, 8″, 10″, and 12½″ reflectors achieve a new level of optical and mechanical excellence for the serious amateur. These totally integrated telescope systems include everything required for detailed study of the Solar System and Deep Space, and readily permit the observer to grow into more advanced subjects, such as long exposure astrophotography.

Designed by Meade engineers and in continuous production at our Costa Mesa facility, these telescopes possess capabilities generally obtainable only at much higher prices — and they are the only telescopes available which use exclusively the quality Meade components known throughout the astronomical world.

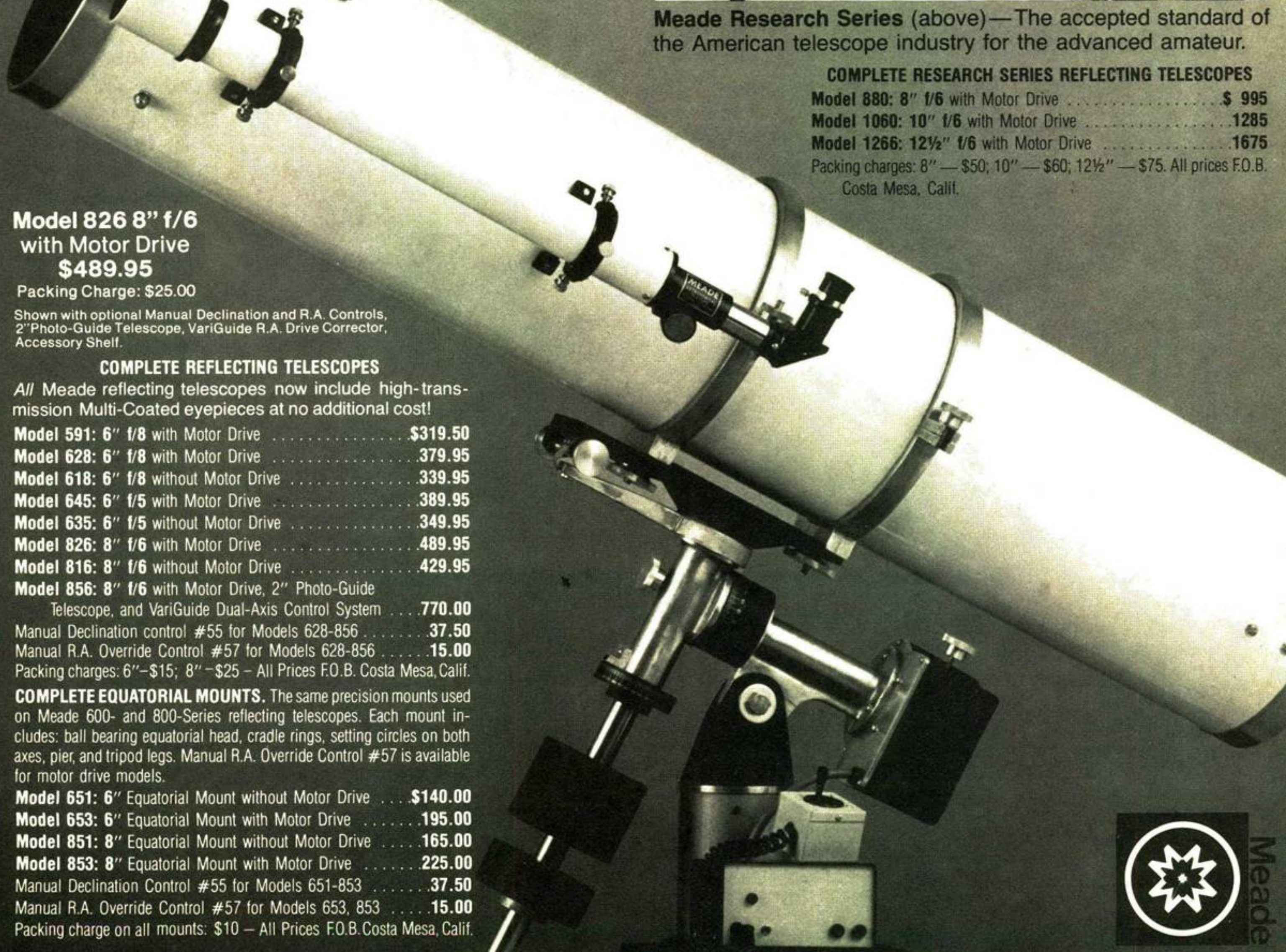


Meade Research Series (above)—The accepted standard of the American telescope industry for the advanced amateur.

COMPLETE RESEARCH SERIES REFLECTING TELESCOPES

Model 880: 8″ f/6 with Motor Drive	**$ 995**
Model 1060: 10″ f/6 with Motor Drive	**1285**
Model 1266: 12½″ f/6 with Motor Drive	**1675**

Packing charges: 8″ — $50; 10″ — $60; 12½″ — $75. All prices F.O.B. Costa Mesa, Calif.



Model 826 8″ f/6
with Motor Drive
$489.95
Packing Charge: $25.00

Shown with optional Manual Declination and R.A. Controls, 2″ Photo-Guide Telescope, VariGuide R.A. Drive Corrector, Accessory Shelf.

COMPLETE REFLECTING TELESCOPES

All Meade reflecting telescopes now include high-transmission Multi-Coated eyepieces at no additional cost!

Model 591: 6″ f/8 with Motor Drive	**$319.50**
Model 628: 6″ f/8 with Motor Drive	**379.95**
Model 618: 6″ f/8 without Motor Drive	**339.95**
Model 645: 6″ f/5 with Motor Drive	**389.95**
Model 635: 6″ f/5 without Motor Drive	**349.95**
Model 826: 8″ f/6 with Motor Drive	**489.95**
Model 816: 8″ f/6 without Motor Drive	**429.95**
Model 856: 8″ f/6 with Motor Drive, 2″ Photo-Guide Telescope, and VariGuide Dual-Axis Control System	**770.00**
Manual Declination control #55 for Models 628-856	**37.50**
Manual R.A. Override Control #57 for Models 628-856	**15.00**

Packing charges: 6″–$15; 8″–$25 – All Prices F.O.B. Costa Mesa, Calif.

COMPLETE EQUATORIAL MOUNTS. The same precision mounts used on Meade 600- and 800-Series reflecting telescopes. Each mount includes: ball bearing equatorial head, cradle rings, setting circles on both axes, pier, and tripod legs. Manual R.A. Override Control #57 is available for motor drive models.

Model 651: 6″ Equatorial Mount without Motor Drive	**$140.00**
Model 653: 6″ Equatorial Mount with Motor Drive	**195.00**
Model 851: 8″ Equatorial Mount without Motor Drive	**165.00**
Model 853: 8″ Equatorial Mount with Motor Drive	**225.00**
Manual Declination Control #55 for Models 651-853	**37.50**
Manual R.A. Override Control #57 for Models 653, 853	**15.00**

Packing charge on all mounts: $10 – All Prices F.O.B. Costa Mesa, Calif.

Meade

Research level telescope parts and accessories from America's No. 1 supplier to the serious amateur

RACK-AND-PINION FOCUSERS—Precision metal construction. All 3 models include helical-cut rack and variable-tension adjustment for ultra-smooth focusing without backlash. Universal bases fit all tube sizes. Standard 1¼" eyepiece holders. **Each focuser is guaranteed to be the finest obtainable in its class:**

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2—MODEL 640—A heavy-duty deluxe focuser for 6" to 16" telescopes. Full 3" travel for both visual and photographic applications. **$35.95 ppd.**

3—MODEL 680—Our finest focuser. Accepts both 1¼" and 2" eyepieces. Full 3" travel for photo or visual observing with 6" to 16" telescopes. **$42.95 ppd.**

4—NEBULAR FILTER—This revolutionary 3-channel filter effectively blocks sodium and mercury emissions from city lights as well as natural airglow, while transmitting 90% of critical visual nebular emissions. Dramatically improves telescope performance visually and photographically. Hermetically sealed, anti-reflection coated. 23mm clear aperture. Threads directly into all Meade 1¼" O.D. eyepieces. **$59.95 ppd.**

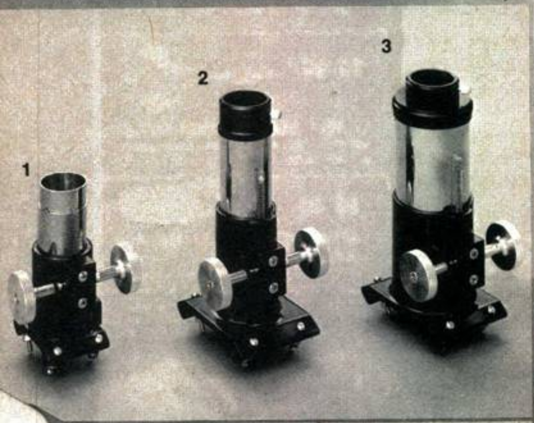
5—PHOTO-VISUAL COLOR FILTERS—Top quality optical glass, dyed-in-the-mass, with excellent spectral homogeneity. Mounted in machined metal cells which thread directly into all our 1¼" "Series 1", "Series 2", and "Research-Grade" eyepieces. Filters may be piggybacked. Listed by Wratten No. and color: **#8 Light Yellow—#11 Yellow-Green—#12 Yellow—#21 Orange—#23A Light Red—#25A Red—#47 Violet—#58 Green—#80A Blue—Polarizer (30% transmission).** Each filter: **$7.95 ppd.** Set of any 6: **$44.50 ppd.**—Full set of 10: **$73.50 ppd.**

6—VARIPAK DRIVE CORRECTOR—Model 43—A quality electronic guiding unit with supercompact (2" × 3" × 4") design. Fast-slow pushbuttons mounted on the power pack. Variable control for lunar, planetary, sidereal rates. Operates from 12 volts D.C., plugs into standard auto cigarette lighter. The 12-watt output is sufficient for most telescopes to 14" aperture. **$49.95 ppd.**

7—VARIGUIDE DRIVE CORRECTOR—Model 41—The finest R.A. drive corrector available. Includes aircraft-type joystick controller for continuously variable correction rates, not just "ON-OFF". May be used with any motor-drive-equipped telescope rated up to 12 watts, including most commercial telescopes to 14" aperture. Operates from 12 volts D.C. or 115 volts A.C./60Hz. Control box includes variable center-frequency settings for lunar, planetary, sidereal rates. **$119.95 ppd.**

8—6×30mm VIEWFINDER—Fine wide-field finder, the same unit supplied as standard equipment on Meade 6" and 8" reflecting telescopes. Actual field-of-view in excess of 4°. Includes coated, achromatic objective lens and crosshair eyepiece. Precise push-pull focusing. Thousands now in use. 2-ring bracket, with collimation screws and lock-nuts, included. Bracket fits all tubes 6" to 12½". **$22.95 ppd.**

9—6×30mm RIGHT-ANGLE VIEWFINDER—As in (8), but with diagonal prism for convenient right-angle observations. Prism may be rotated through 360° for maximum viewing comfort. 2-ring bracket included. **$27.95 ppd.**



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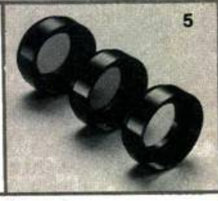
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Multi-Coated Series 2 and Research-Grade Eyepieces

Manufactured to entirely new Meade designs, these Series 2 eyepieces are a significant advance in eyepiece technology. Utilizing modern high-density optical glasses, each eyepiece has been computer optimized to yield the highest level of optical performance obtainable within its design class. **Air-to-glass surfaces on all Series 2 and Research-Grade eyepieces are Multi-Coated for maximum light transmission and image contrast.** All 1¼" barrels are threaded for Meade filters.

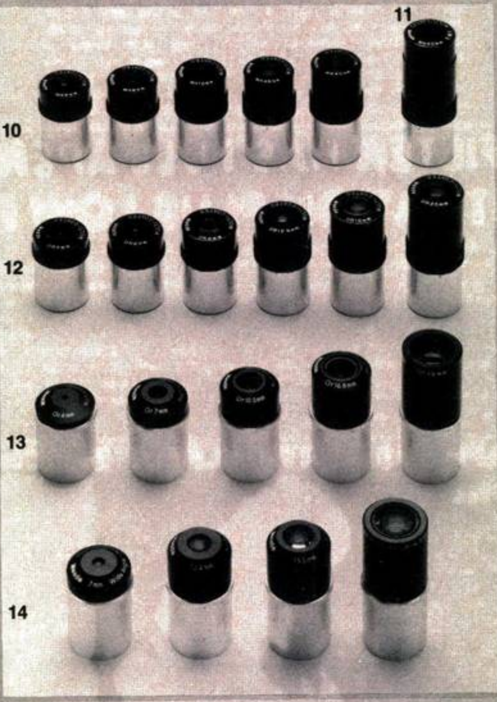
10—SERIES 2 MODIFIED ACHROMATIC EYEPIECES (1¼"O.D.; MULTI-COATED)—Fine 3-element systems, precisely corrected for chromatic and spherical aberrations. Guaranteed to be the finest eyepieces obtainable in their price class.
FOCAL LENGTHS: MA 6, 9, 12, 25mm and 40mm Wide-Field .... each $19.50 ppd.

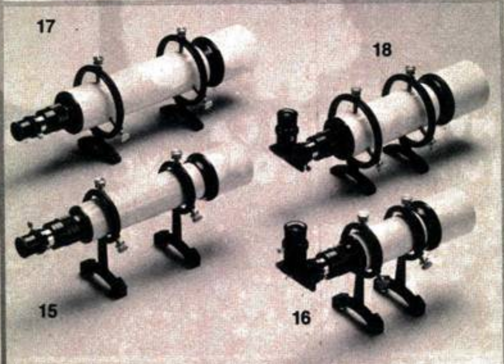
11—MODIFIED ACHROMATIC 40mm EXTRA-WIDE-FIELD EYEPIECE (1¼" O.D.; MULTI-COATED)—Yields widest field obtainable in 1¼" O.D. Enlarged field lens and special field-flattening optics with long eye relief. **$27.75 ppd.**

12—SERIES 2 ORTHOSCOPIC EYEPIECES (1¼" or .965" O.D.; MULTI-COATED; PARFOCAL)—The excellent 4-element high resolution optics of these oculars are all that the majority of serious amateurs will ever require. Razor sharp 45° fields. Both the 1¼" and .965" O.D. sets are accurately parfocalized.
FOCAL LENGTHS: OR 4, 6, 9, 12.5, 18, and 25mm...each $27.95 ppd.

13—RESEARCH-GRADE ORTHOSCOPIC EYEPIECES (1¼" O.D.; MULTI-COATED; PARFOCAL)—The largest selling premium-quality eyepieces in the world, universally acclaimed to be the finest eyepieces obtainable. These 4-element systems are unsurpassed in color correction, resolution, and flatness of field. 45° field. Accurately parfocalized.
FOCAL LENGTHS: OR 4, 7, 10.5, 16.8, 28mm...each $39.50 ppd.

14—RESEARCH-GRADE ERFLE EYEPIECES (1¼"O.D.; MULTI-COATED; PARFOCAL)—For breathtaking wide-angle observations. 65° to 75° fields, parfocalized with our Research-Grade Orthoscopics.
FOCAL LENGTHS: ER 7, 12.4, 15.5, 20mm...each $42.50 ppd.





VIEWFINDERS—With helical focusers for ultraprecise control of image sharpness. Coated, achromatic objectives of new Meade design yield fully corrected images throughout the field. Actual field on 50mm models: 5°; on 60mm models: 4½°. Crosshair eyepiece, dewcap, dustcap included. The 60mm models are particularly recommended for telescopes 8" and larger, where the large finder aperture is a tremendous aid in the location of faint objects.

15—8×50mm—$39.50 ppd. Brackets: **$7.95/pr. ppd.**

16—8×50mm RIGHT-ANGLE—$46.50 ppd. Brackets: **$7.95/pr. ppd.**

17—GIANT 9×60mm—$62.50 ppd. Brackets: **$12.75/pr. ppd.**

18—GIANT 9×60mm RIGHT ANGLE—$69.50 ppd. Brackets: **$12.75/pr.**

19—RESEARCH-GRADE ERFLE 32mm EYEPIECE (2"O.D.; MULTI-COATED)—Wide-angle, fully-corrected 65° field. The finest eyepiece obtainable in 2" barrel. **$84.95 ppd.** Adapter Barrel for 1¼"O.D. ...**$7.50 ppd.**

20—DELUXE CAMERA ADAPTERS—Adapt your camera to telescope focuser instantly. Individually machined from solid bar aluminum and brass. All units permit both eyepiece-projection and first (prime) focus photography. Specify either 1¼" or .965" focuser. All 1¼" units are threaded for our filters. **Pentax, Yashica, Mamiya...$18.95 ppd.—Nikon, Canon, Minolta, Pentax K, Exakta, Konica, Olympus OM-1, OM-2...$26.75 ppd.**

21—2X TELENEGATIVE AMPLIFIER (1¼" O.D.; MULTI-COATED)—Model 122: Warranted without qualification to be the world's finest Barlow lens. Full 26mm clear aperture, Multi-Coated, with virtually flawless optical corrections at all photo-visual wavelengths. Produces optimum performance on telescopes of any focal ratio...**$29.50 ppd.** **Model 131:** Per Model 122, but for .965" focusers; 18mm clear aperture, Multi-Coated...**$24.50 ppd.**

22—2X-3X VARIABLE TELENEGATIVE AMPLIFIER (1¼" O.D.; MULTI-COATED)—Model 127: Manufactured to the same research standards as the Model 122 above, but mounted in a precisely machined sliding cell, to permit variable power settings between 2X and 3X. Engraved scale indicates power. Multi-Coated...**$36.50 ppd.**

23, 24—ACCESSORY CASES—Rugged polyethylene, for dust-free protection of eyepieces, filters, Barlows, etc. Die-cut foam lining. **Model 51: 7" × 8½"... $8.95 ppd.—Model 54: 8" × 12"...$12.95 ppd.**

25—ILLUMINATED RETICLE GUIDING EYEPIECE (1¼" or .965" O.D.)—New phosphorescent etched double-line reticle permits line illumination from dim to extremely bright. Remote brightness control and 6 ft. cable. Modified Achromatic 12mm optical system. Precisely focusable reticle. Complete...**$49.95 ppd.**
Micrometer Reticle. Full-field scale for accurate measurements of double star separations, planetary angular diameters, etc. Interchanges with standard 4-line reticle...**$14.95 ppd.**

26—ERECTING PRISMS—Fully coated Porro prisms, for terrestrial observations with astronomical telescopes. **1¼" O.D. ...$32.95 ppd.**
.965" O.D. ...$24.95 ppd.

27—DIAGONAL PRISMS—Quality right angle prisms, fully coated. **1¼" O.D. ...$19.95 ppd.—.965" O.D. ...$14.95 ppd.**

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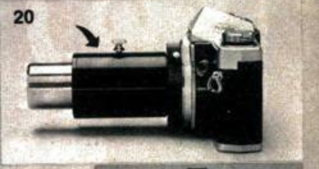
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Tired of dim images and mirror vibration?

THE PRAKTICA CONVERTIBLE

is ideal for astronomical, microscopic and general photography

← FOR ASTRO/MICRO PHOTOGRAPHY

● Clear aerial image and point source (star) focusing with custom screen, 5X magnifying, diopter correcting eyepiece finder ● Gentle knob film advance (removable) ● Minimum mirror slap with patented system ● Air bulb shutter release for planetary (sun, moon, planets) exposures ● Locking cable release for long exposures ● Large mirror has very little cutoff ● Can be used for piggyback, first (prime) focus and eyepiece/Barlow projection ●

FOR GENERAL PHOTOGRAPHY →

● Pentaprism ● Focusing screen ● Lever film advance ● Self timer ● Multicoated automatic 50mm F/1.8 lens focuses to an incredible 13 inches (very sharp and suitable for wide-field piggyback photos) ● Built-in light meter works through the lens and can be used with pentaprism or 5X magnifying finder ● Flash socket ●

This wonderful camera, which serves so many purposes so well, is supplied with a beautiful soft carrying case and neck strap. The body weighs only about 22 ounces and contains an all *steel* focal plane shutter with speeds of 1 to 1/1000 second plus bulb and electronic flash. It accepts any universal (Pentax) thread lens and its light meter has both wide-open and stop-down settings. An indicator is viewable through the finders so that correct exposure settings are readily visible. The finders and view screens (two screens) can be changed in seconds. The patented system which releases the shutter permits the photographer to "monitor" the photo. That is, by observing the image you may wait for "steady seeing", trip the mirror to reduce vibration and then take the photograph. The air bulb release does all the action required and unlike many other cameras that have a pre-release mirror system, the photographer does not have to touch the camera, which induces vibration and causes telescopic images to shift. Most other cameras leave one "blind" between exposures with their mirror-lock mechanisms and require the sacrifice of some film. Still others use a split-beam mirror to overcome the mirror vibration problem but at a loss of light. *Any* loss of light at the film plane and focusing screen is totally undesirable in astrophotography. Other cameras which cope with some of these problems are usually not suitable for prime focus and piggyback uses. The custom clear screen utilizes a *double* crosshair in order to render the most accurate and ultra-bright image possible. Single crosshair screens simply will not do! In addition to all the features described, a metal body cap and front and rear lens caps are also included. How much does all this cost? The nearest camera to it with similar features and accessories, the modified Nikon F, has a price tag of $875.55! The PRAKTICA CONVERTIBLE, available *only* from R. T. Little, is $325.00. Adapter rings for DYNAMAX, CELESTRON and QUANTUM telescopes are $10.00. The QUESTAR does not require a ring. 1¼″ and .96″ adapters and microscope adapters cost $25.00. Camera without lens, case, extra screen and pentaprism (ready for astronomical and microscopic photography) is $278.00. This superb camera comes with a one year limited warranty and is serviced around the world.

SAFE SUN/MOON FILTER HAS FULL APERTURE AND VENTILATION PLUS LOW PRICE

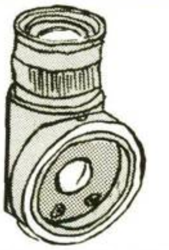
This safe filter is not only very inexpensive (as such things go) but it also has features not found in competitive makes. It mounts magnetically to the DYNAMAX six- and eight-inch telescopes, the CELESTRON eight-and fourteen-inch telescopes and all reflectors of these same sizes. The magnetic mount is supplied with the filters making a system that provides full ventilation around the edge which prevents resolution-robbing heat traps. The golden thin film used in this filter will not shatter if dropped and yet its resolution is just as fine as the full aperture glass filters. Also, and very important, the special system used renders the sun a familiar orange color unlike some which make the sun appear an unnatural bluish color. These filters are truly bargain priced: 6-inch $28.00, 8-inch $33.00, 14-inch $55.00. Please state instrument size and manufacturer. No other sizes. Patent pending.

INSTANT ASTROPHOTOGRAPHY IS VERY HELPFUL IN SCHOOLS AND FUN FOR EVERYONE

Beautiful instant color photos of the sun, moon, planets and terrestrial subjects are easy and rewarding to take through telescopes using this patented adapter kit and an SX-70 Polaroid Land camera. (This kit is compatible with the *reflex* models only. Not the Pronto nor any other "instant" camera.) This system was reviewed in the August 1975 issue of Astronomy magazine and is "must" reading for prospective users. You may obtain a copy by sending $2.50 to them at 411 East Mason, 6th Floor, Milwaukee, Wi. 53202. The availability of this telescope adapter kit was announced by Polaroid Corporation in the September 1975 issue of Scientific American magazine and has their official endorsement. The kit for DYNAMAX, CELESTRON, QUANTUM and QUESTAR telescopes is $125.00. A kit for other telescopes having 1¼″ ocular holders is also $125.00 but requires the use of .96″ oculars. Specify the brand of instrument for which the kit is intended.

KIT ON DYNAMAX®

SX-70® PHOTOGRAPH



CONVERT YOUR CAMERA LENS TO A TELESCOPE/FINDER

This fine right-angle Amici prism with screw-in 18mm focusable ocular attaches to most camera lenses and provides a fully correct view. The power is determined by dividing the 18mm focal length of the ocular into the focal length of the lens with which it is used. The prism housing has a ¼x20 thread in its bottom and attaches to tripods and "piggyback" mounts. Specify "T" thread or Universal (Pentax). The price of this prism with ocular is $37.00. Adaptations for lenses with other mounts are $12.00.

ORDERING AND DELIVERY INFORMATION FOR THESE ASTRONOMER'S AIDS

All the items listed are generally in stock, but because the influx of orders cannot be predicted, delivery can take up to five weeks. If a delay in excess of this time is likely, a notice will be sent. All prices include delivery. SPECIAL BONUS: Orders of $100.00 or more will have a magnifying red light included free, and orders exceeding $324.00 will have the light, an astronomer's penlight or camera adapter ring and a 12 volt dew remover included free, if payment is made in the form of U.S. POSTAL SERVICE or INTERNATIONAL POSTAL money orders. This form of payment also speeds delivery. Personal checks which are not certified take three weeks to "clear". American schools that **prepay** orders are entitled to the above bonus items. FOREIGN orders, including schools, must be **prepaid** in U.S. funds. For air delivery outside the U.S. and Canada, add 7% of the total order. Surface shipment is free. New York residents must add proper sales tax.

→ A CATALOG IS NOT AVAILABLE, BUT IF SPECIFIC QUESTIONS NEED ANSWERING PLEASE WRITE OR TELEPHONE. ←

Robert T. Little
P.O. Box E — Dept. M2
Brooklyn, N.Y. 11202
212/834-1888

Formerly with Questar and Celestron, Mr. Little is Field Sales Manager for Criterion Scientific Instruments, makers of DYNAMAX telescopes, and President of Astronomy Island Ltd. For many years he served as astrophotography instructor at New York's Hayden Planetarium and is well known for his solar eclipse expeditions. His eclipse photo appeared on the April 1979 cover of LIFE magazine. He will co-lead various scientific expeditions for Star & Sky magazine. Bob holds three patents and has a fourth pending for various astronomer's aids.

$29.50

AUTOMOBILE TELESCOPE POWER unit converts 12 v.d.c. to 110 v.a.c. up to 40 watts. Transistor accuracy! Plugs in dashboard.

$11.00

12 VOLT HEATED BLOWER evaporates moisture from the front lens of telescopes in seconds. Plugs in dashboard. Eliminates expensive, awkward dewcaps.

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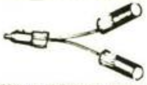


12 VOLT DOUBLE POWER OUTLET permits the use of two accessories at the same time. Use with above.

$6.00

EXPENSIVE MAGNIFYING RED LIGHT makes star maps, camera settings, scope circles easy to read. Comes with red & white bulbs. Batteries not guaranteed.

$10.95

VERY EXPENSIVE ASTRONOMER'S PEN/LIGHT casts small red beam with a ball point in the center. Great for making notes at the telescope and in darkened classrooms. Two ball points and batteries supplied. Batteries not guaranteed.

$39.50

LOW COST LED STOPWATCH makes the timing of photos, occultations, etc. easy. No more flashlights to fumble. Runs hours on readily available AA cells.

photograph the perseids

photography
in
astronomy

Rick Schmidt

Meteor photography has to be the easiest type of astrophotography, bar none. Anyone owning a camera capable of time exposures can do it. Load up with fast film, place the camera on a tripod, focus on infinity and open the lens to its widest aperture, aim at the sky, and start your exposure. *That's it.*

To record the maximum number of meteors, you have to take a few extra precautions, but they're very simple. Here are some hints: Since the annual shower of Perseids (peak time: August 12th) appears to come from one part of the sky (called the radiant) near the Perseus-Cassiopeia border, aiming your camera in the vicinity of this point will increase your chances for nabbing a meteor as it flashes along. The optimum place is 45° or so away from the radiant, for there you see the meteors as streaks and your field of view encompasses the largest volume of atmosphere.

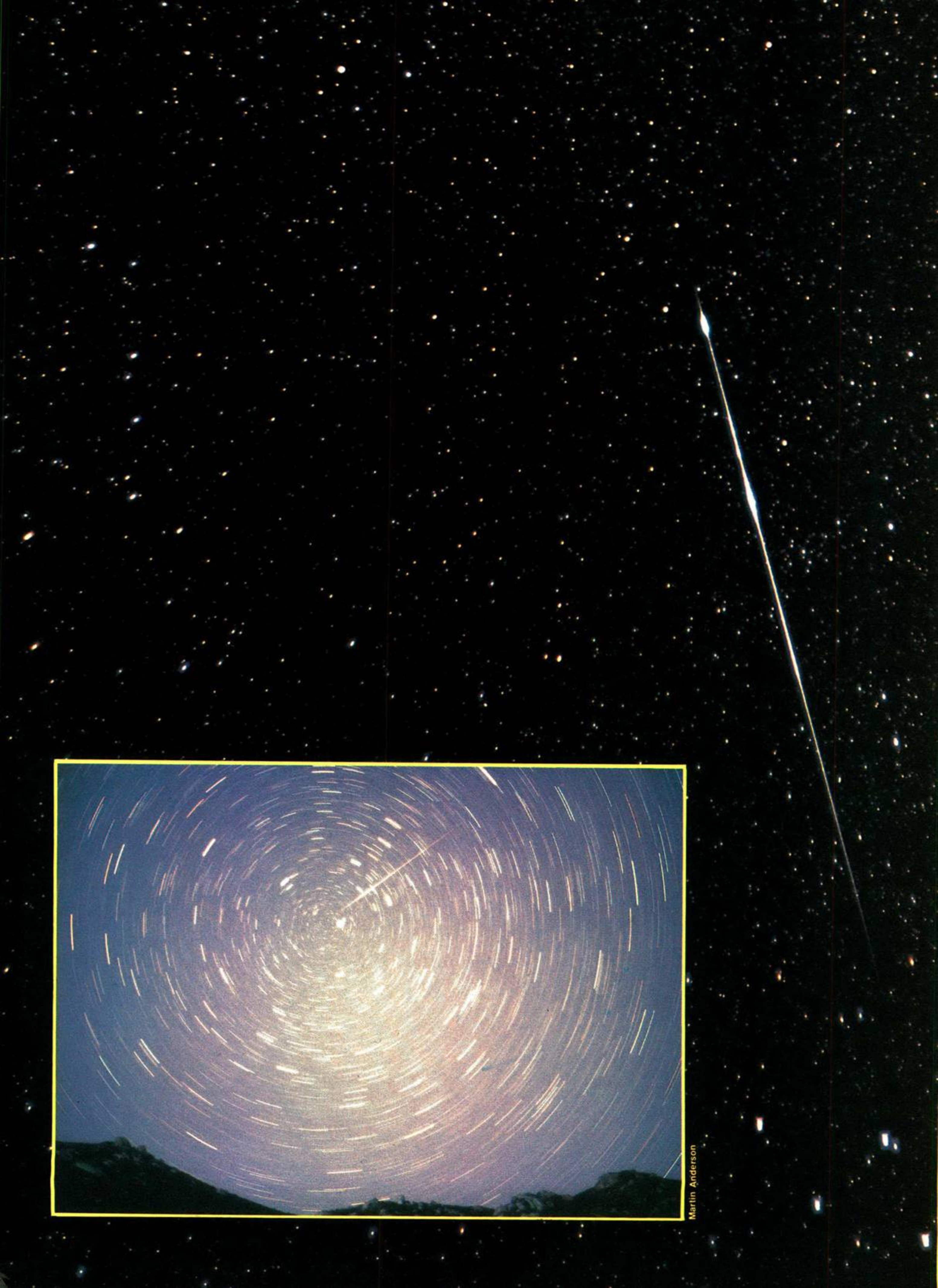
The wider the angle of view of your lens, the more sky it sees and the more meteors it's liable to catch: a 28 mm lens covers nearly four times the area of a 50 mm lens. Two drawbacks are that wide-angle lenses usually aren't as "fast" as the average normal lens, and their image scale is less, making meteors appear smaller.

The film you use should be 400 ASA or faster. Since you can get black and white as well as color films (slide and negative) with this speed, never use anything slower. If you have the processing done commercially, expect to have problems. Automated processing machines just aren't set up for the requirements of astrophotography. For all negative films, it's best to make your own prints, and for slides insist that they be returned unmounted (or you'll get frames chopped in two).

You can put the camera on a tripod and get star trails with your meteors, or it can be piggybacked on an equatorial mounting to render stars as points of light. The former is easier, but the latter shows the background constellations better.

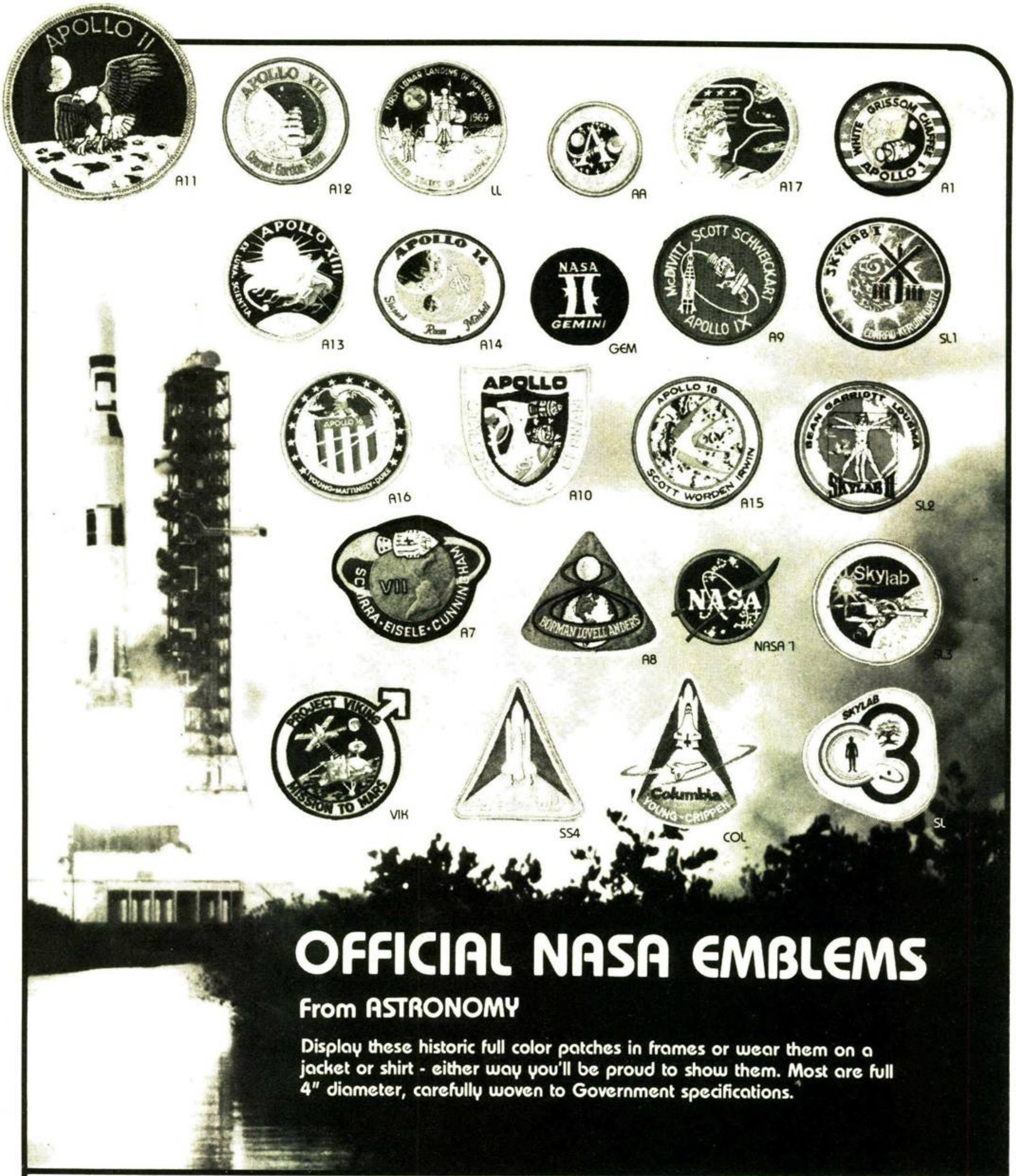
Run your exposure until you get a bright meteor through your field of view or until sky fog begins to wash out the stars, whichever comes first. Trial and error (ahead of time!) will show how long it's safe to expose a given film with your equipment at your observing site.

— *Robert Burnham*



Martin Anderson

Peter Nowak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APOLLO 15
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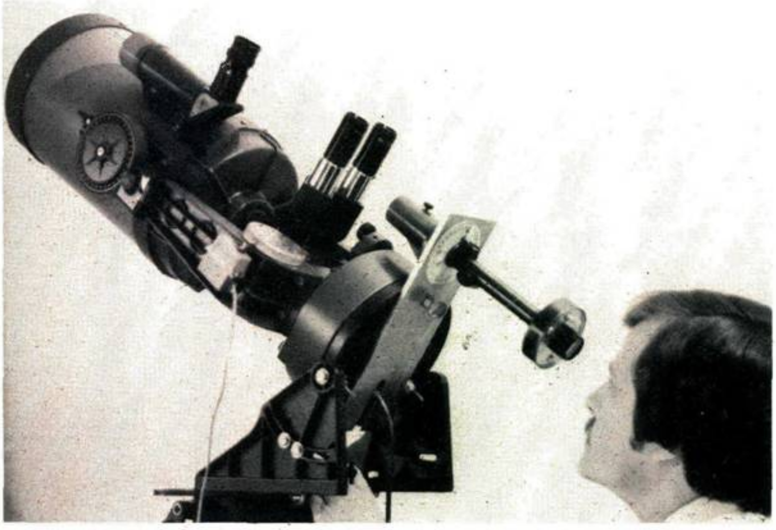

Kerry D. Martin shown aligning his Celestron 8 with OUR Celestial Polar Axis Finder

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ASTRONOMY IN FOCUS

DANGER WARNING: Do not use carbon tetrachloride as suggested in "How to Build a Dobsonian Telescope, Part 2," July 1980, page 43. **CARBON TETRACHLORIDE IS EXTREMELY POISONOUS.** It can enter your bloodstream directly through skin and cause liver and brain damage. Symptoms do not appear immediately; they are nausea, dizziness, jaundice, and coughing. Please write this warning directly into your copy of the July issue.

Lunar Industrialization

Sir / After reading "Return to the Moon" by Michaud and David in the April 1980 issue, I have one nagging question: Is there any evidence for ore deposits of cosmologically scarce metals on the Moon or on any body too small or too hot to have ever had oceans and/or large amounts of water percolating through its crust?

To form a vein or rich ore deposit from atoms scattered here and there through rock, solution, restricted flow, and localized precipitation are necessary. And however magnesium nodules grow, they grow on the ocean bed, not amid the deserts of Mars. In the absence of water to transport them, atoms won't selectively congregate in rock.

"Return to the Moon" gave an analysis of the normal moonrock. Aside from a concentration of refractory titanium and the absence of volatile sodium and potassium, the metal concentrations are within a factor of two of terrestrial abundances for the cosmologically abundant elements. This makes sense, as the Moon and Earth condensed from the same nebula as did all other bodies in the solar system. For a first approximation we may assume that the Earth and Moon have the same relative abundances of the scarce metals.

So, working from a list of terrestrial abundances for the scarce metals, and the abundances of the four commonest lunar metals, will give you an idea of how slim the pickings will be for most metals:

Metals Contained in 1,000,000 Tons of Moonrock

Aluminum	120,000	tons
Titanium	60,000	tons
Iron	40,000	tons
Magnesium	30,000	tons
Manganese	1,000	tons
Nickel	72	tons
Copper	58	tons
Niobium	20	tons
Lead	10	tons
Thorium	5.8	tons
Tantalum	2.4	tons
Uraninum	1.6	tons
Tin	1.5	tons
Molybdenum	1.2	tons
Tungsten	1.0	ton
Silver	80	kg.
Platinum	5	kg.
Mercury	2	kg.
Gold	2	kg.

On Earth, it isn't economical to process copper ore with a grade of less than 0.1%, or 1,000 tons metal per 1,000,000 tons of rock. Thus, it seems the Moon has workable ore deposits of four metals: aluminum, titanium, iron, and magnesium, with manganese being on the borderline of easy recoverability. In the absence of natural concentrations, the only way to get at the trace metals would be to tear the rock apart, atom by atom. It would require less energy to import all cosmologically scarce metals from Earth.

An alternative would be to learn how to make do with only the four common metals — no need to worry about iron rusting or magnesium catching fire in a vacuum! But we should not expect the Moon or the asteroids to help us cope with shortages of a dozen metals fifty years hence. The days of gobbling up copper and lead by the megaton are numbered, and the industrialization of space will not change this fact.

Michael J. Sloboda
Maryknoll, NY

NASA & the Media

Sir / In response to Mr. Davis' article in the March Forum, it seems no month goes by that we don't hear of developments in Congress that literally kill our plan for a future in space. President Carter's plan to balance the federal budget will certainly mean more budget cuts for NASA.

The fact is, there simply aren't enough of us who are sufficiently active to make the message public. Part of the existing problem lies with the networks. Their appalling coverage of the achievements of NASA last year had me red with frustration. Checking through the list, we had Pioneer Venus arrive at, and study, that planet with a complex assembly of atmospheric probes and an orbiter. In March, we watched Voyager 1 pass Jupiter, staggering the readers of this and other science-oriented magazines with discoveries. In July, we had a follow-up performance by Voyager 2. Finally, in August and September, Pioneer 11 encountered Saturn after drifting in space for more than half a decade.

From the beginning, I was sure that '79 would be the year that NASA would get back on its feet and receive some worthy recognition for its super work. Contrary to my expectations, each mission received about thirty seconds of televised recognition — except Pioneer 11, which received none. It's true, the newspapers devoted more time, sometimes giving as much as a column on the first page.

My point is that we need so little "to ignite our spirit of adventure and exploration," as Mr. Davis put it. I read about the missions and I certainly don't need that dream revived. It is very much a part of me. What we need is to express this to others...to pass the feeling around until it becomes powerful enough to effect changes in government policy.

Although I was frustrated by the

major networks' policies of skimming over NASA's achievements, I'm frustrated even more by the fact that so few people have said anything about it. In the good name of the scientific community, I'm not going to let another mission go by without letting my corner of the country know about it. And I won't need network time to do it!

Andrew Martin
Exeter, NH

Teflon

Sir / I just read your first article on building a Dobsonian telescope in the June issue, and thought that anyone interested in building one would like to know that small pads of teflon are easily obtainable through ski equipment dealers. The pads are placed under ski boots to reduce friction between the boot sole and the ski during an emergency release of the binding. I don't have any idea what these pads cost, but I'm sure it's minimal.

William R. Sternberg
Noank, CT

Sir / Re: The Dobsonian telescope construction article in the June issue, the following address will get you any size teflon material no matter how small:

Frank Wirt W9TFY
Alpha, IL 61413

Please send a S.A.S.E. for list of thicknesses available.

Bill Terrell
Hillsboro, OH

The Moon Illusion

Sir / Reading the article "Watching the Lunar Phases" in the June 1980 issue brought back some fond recollections of a month I spent working an outside night shift last year. Being out for over a month, I was able to view a complete lunar cycle. As the phase gradually turned to full and the Moon slipped from the western sky into the east, I could almost watch the Moon shrink from its large size and orange color to its "regular" size in about 20 minutes.

Being the one to always answer astronomical questions, I explained to an inquisitive friend about the magnifying effect of our atmosphere that produces the noticeable variation in the Moon's size and color. I don't like to give a wrong answer, even if it's only half wrong, so imagine my surprise to read in your article under the subtitle "The Moon Illusion": "...it's curious that no one has a really satisfactory theory to explain it."

If we can figure out that a chain of supernovae a few billion years ago caused the contraction of our solar system, can't we figure out why the Moon looks bigger near the horizon?

Michael T. Marc
Lombard, IL

Sir / The last few days of May I saw the Moon come up over the horizon with a tannish brown color to it. But by 11:00 p.m. EST the Moon would be back to its bright white color. This was all natural to me since this has happened so many times before.

Then on May 30 at 10:00 p.m. EST the Moon (14½ hours past full phase) at about 20 degrees above the horizon, was staring at me with a red face. I had never seen the Moon that deep a red before; in fact, I never remember seeing it that color in a pitch black sky before. What makes the Moon turn these colors at all?

J. Scott Langworthy
South Glens Falls, NY

Mr. Langworthy / The colors are produced by the scattering of moonlight in our atmosphere. When the light has to travel through a lot of air (as at rise or set) the color becomes very pronounced, as you have noted. Mt. St. Helens probably helped, too!

Naked-eye Viewing?

Sir / Skylore (May 1980) features an illustration for naked eye-viewing (*sic*), but it is of Andromeda and not of Virgo or Berenice about whom you write so extensively.

Gerald Johns
San Diego, CA

Mr. Johns / The illustration was chosen (1) to represent "female" constellations in general, (2) because Andromeda was more beautiful than Persephone, Berenice, or Cassiopeia, and (3) because she was more likely to be found unclothed!

Ooops!

Philip Stahl is a post-graduate research student at the University of the West Indies, not a solar physicist as stated in the May Stellar Frontiers.

behind the scenes

the tale behind the telescope

With this issue, we conclude our Equipment Atlas mini-series on building a 10" Dobsonian telescope. Those of you who keep up with the comings and goings of ASTRONOMY's telescope-building Editor through TELESCOPE MAKING magazine may remember the little article in Forum last July about the Riverside Telescope Maker's Conference, which is held annually near Big Bear Lake in California. There, a large number of home-built telescopes were on display. Some were the product of hours and hours of superb craftsmanship at a basement lathe, others the assembly of chance bits of pipe and gears, or tubing and tape. Among them were several beautifully functioning examples of the Dobsonian telescope. Your Editor, acting on behalf of TELESCOPE MAKING, wheedled and cajoled, begged and pleaded, and finally published in TELESCOPE MAKING a number of fine articles on how to go about building one of these instruments.

Well, the response was enormous. TM readers deluged us with questions. Then, when the Forum interview with John Dobson (in the April issue) elicited strong response from ASTRONOMY's readers, we decided to go ahead with the three-part series so that readers who never previously thought of themselves as telescopes builders could put together a powerful instrument for a low price.

Meanwhile, because of the requests for the articles on Dobsonians that appeared in TM, we went to press with a 36-page booklet of reprint articles from TM. We are pleased with your interest, and hope, with the series in ASTRONOMY and the TM reprint booklet, that a lot of people who might never have gotten into active observational astronomy will give it a try.

Sincerely,

Richard Berry

Richard Berry

ASTRONOMY REVIEWS

Planetary Geology

John Guest with
Paul Butterworth,
John Murray and
William O'Donnell
208 pages, hardcover, $19.95
John Wiley & Sons (1979)

Planetary geology is a science that has come into its own only in the past decade or so, but its origins extend further into the past than most people realize: The Greek philosopher Democritus guessed that the various markings on the Moon were due to features such as mountains and valleys. Although Democritus' speculations were based solely on unaided-eye observations, his ideas were the first recorded geological interpretations applied to a celestial object.

But it was Galileo's telescopic studies of the Moon that marked the real birth of planetary geology. In effect, much of early planetary astronomy might also have been termed planetary geology since it relied heavily on the interpretation of observed planetary surface features. But it has been the incredible barrage of data returned in the past two decades by space probes that has enabled scientists to apply geological thinking more liberally to planetary bodies.

Planetary Geology by John Guest and others is a much needed attempt to introduce the non-specialist to the main geological features and probable processes that shape the surfaces of the Moon, Mars, Mercury, Venus, and the moons of Jupiter. The book is written for readers with at least some knowledge of terrestrial geology, but any intelligent reader can profit from it.

The body of the book consists of 94 pages of planetary photos (almost exclusively from NASA), each of which is faced by a page of explanatory text. Various sections cover topics such as "Farside Lunar Basins," "Mercury: The South Polar Region" and "Degradation of Martian Craters." Each section stands alone and the book may be browsed without the need to read straight through from the beginning.

Understandably, the largest sections deal with the two planetary bodies we have explored most thoroughly: the Moon and Mars. There is also a substantial section devoted to the Mariner 10 photos of Mercury and very brief sections on Venus and the satellites of Jupiter. The book was written shortly after the Pioneer Venus mission and Voyager I's passage through the jovian system, and consequently data from these missions are at a minimum. There is no discussion of the non-terrestrial planets (Jupiter, Saturn, Uranus, Neptune, and Pluto).

Since *Planetary Geology* deals solely with the interpretation of photos of planetary surfaces, there is none of the lunar mineralogy or meteorite studies which form significant parts of similar books, such as *Planetary Geology* by Nicholas Short or *Space Geology* by Elbert King. Guest should perhaps have named the book *Planetary Geomorphology* since it considers only surface formations and not the various other branches of geology.

Jargon such as "en echelon graben," "hummocky ejecta blanket" and "compressional thrust fault scarps" are used casually without explanations (there is no glossary), but this should be no obstacle to readers with access to basic geology texts or a geologic dictionary (available in most libraries).

A more serious problem is with the labeling of photos. The letters and arrows used to mark features are often inconspicuous, making it difficult to relate the photo directly to the text. Very often the photos are not labeled at all, a situation which poses no problem to geologists, but which could prove confusing and frustrating to the inexperienced reader.

Despite this difficulty with labeling and the occasional thickets of geological jargon, *Planetary Geology* is an excellent intermediary between the scant coverage found in elementary astronomy texts and the detailed and often difficult treatment of more advanced works.

The "small personal selection" of black and white photos used in this book are well chosen and reasonably well reproduced. The interpretations which Guest and his associates have given to the photos should serve as a springboard for a more informed inspection of the many thousands of additional NASA photographs currently available. *Larry Sessions.*

Project Icarus

MIT Student Project
162 pages, paperback, $4.95
MIT Press (1979)

This isn't really a new book. In 1968 MIT Press published the first edition of *Project Icarus* which is now being reprinted in a smaller format. The project, assigned to students in a space engineering course, was to devise a way to stop, divert, or destroy asteroid Icarus which was assumed to have a (hypothetical!) collision course with the Earth. Sound familiar? The idea ended up as the recent movie *Meteor* — hence the reprint. Well, this is how you'd do it, in detail.

Astronomy Facts & Feats

Patrick Moore
288 pages, hardcover, $17.95
Guinness Superlatives (1979)

The publisher's name should tip you off: this is a book about the biggest, *smallest, brightest, farthest, closest,* darkest, etc., etc. in astronomy. Written with tongue firmly in cheek at least part of the time, Moore's book is good fun and a useful reference.

The Planet Saturn
A. F. O'D. Alexander
474 pages, paperback, $8
Dover Publications (1980)

Thank heavens for Dover. No one else seems to be interested in reprinting old and out-of-print classics of astronomical literature. Alexander's *Saturn* (published in 1962) is a "history" of the planet — not as it actually is, but rather as our perceptions of it have changed, starting in ancient times. It summarizes and quotes directly from a great many past observers' accounts and thus assembles a lot of widely scattered material.

The Exploding Universe
Nigel Henbest
217 pages, hardcover, $19.95
Macmillan (1979)

Large-format and colorfully illustrated, Henbest's book presents the world of modern astronomy to the layman.

What Is a Star?
Donald Goldsmith
32 pages, paperback, $2.95
Interstellar Media (1979)

Aimed at the very beginner, this booklet answers such questions as "What is a shooting star?", "What is an eclipse?", and "How do rockets work?" in a simple, straightforward manner.

Spotter's Guide to the Night Sky
Nigel Henbest
64 pages, paperback, $1.95
Mayflower Books (1979)

This is a colorful little (pocketsized) book that fulfills what its title promises. It surveys most of astronomy with bright illustrations and tells the reader how to get started making his own observations.

The Cosmogony of the Solar System
Fred Hoyle
168 pages, hardcover, $16.95
Enslow Publishers (1979)

Hoyle's book on the origin of the solar system combines extensive mathematical reasoning with admittedly controversial speculation, such as postulating that life on Earth arrived via cometary collisions. For those who can follow his argument through the equations (or can take the conclusions on faith), this book will be absorbing if not totally convincing.

New Worlds
Wernher von Braun & Frederick Ordway
284 pages, hardcover, $24.95
Anchor Press

Subtitled "discoveries from our solar system," this book covers the growth of present knowledge about the system. The emphasis is on the development of both the scientific ideas and the hardware used to uncover them.

Monsters in the Sky
Paolo Maffei
342 pages, hardcover, $15
MIT Press (1980)

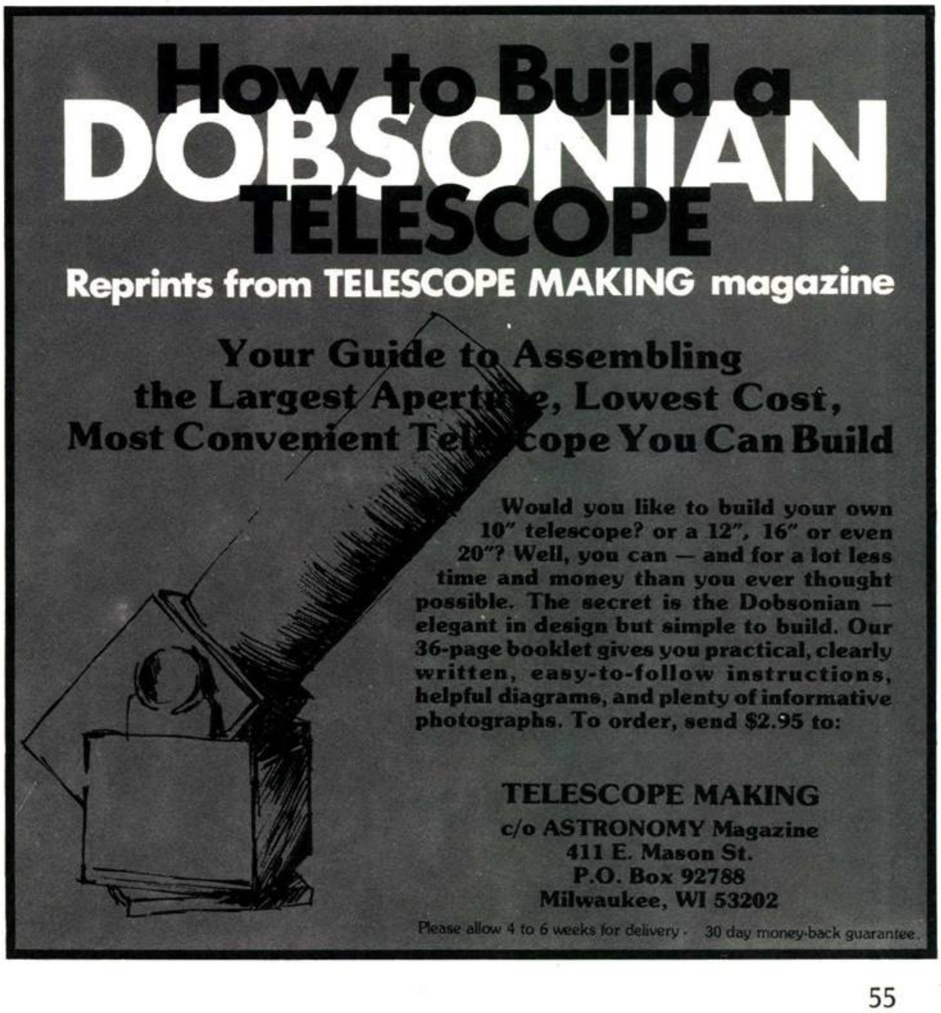
A companion to his earlier *Beyond the Moon*, Maffei's new book describes the unusual and puzzling objects (the "monsters" of the title) modern astronomical research has uncovered. The presentation is engaging and at about the Stellar Frontiers level.

Cosmic Landscape
Michael Rowan-Robinson
149 pages, hardcover, $12.95
Oxford University Press (1980)

Rowan-Robinson takes his reader on a tour of the universe — but with a novel twist. He shows you what the universe would look like, and what objects you'd "see," if you were to confine your vision to various parts of the electromagnetic spectrum (like X-rays, radio waves, ultraviolet, etc.).

Sun, Weather, and Climate
John R. Herman & Richard A. Goldberg
360 pages, paperback, no price given
NASA (1978) [order as NASA SP-426 from Government Printing Office, Washington, D.C. 20402]

The authors aim this book at "researchers in the atmospheric and space sciences," and intend to provide them with an introduction to this recently-emerging subject area. It looks at the correlations between terrestrial weather and climate and solar activity, examines possible causes, and suggests areas where more work could best be done.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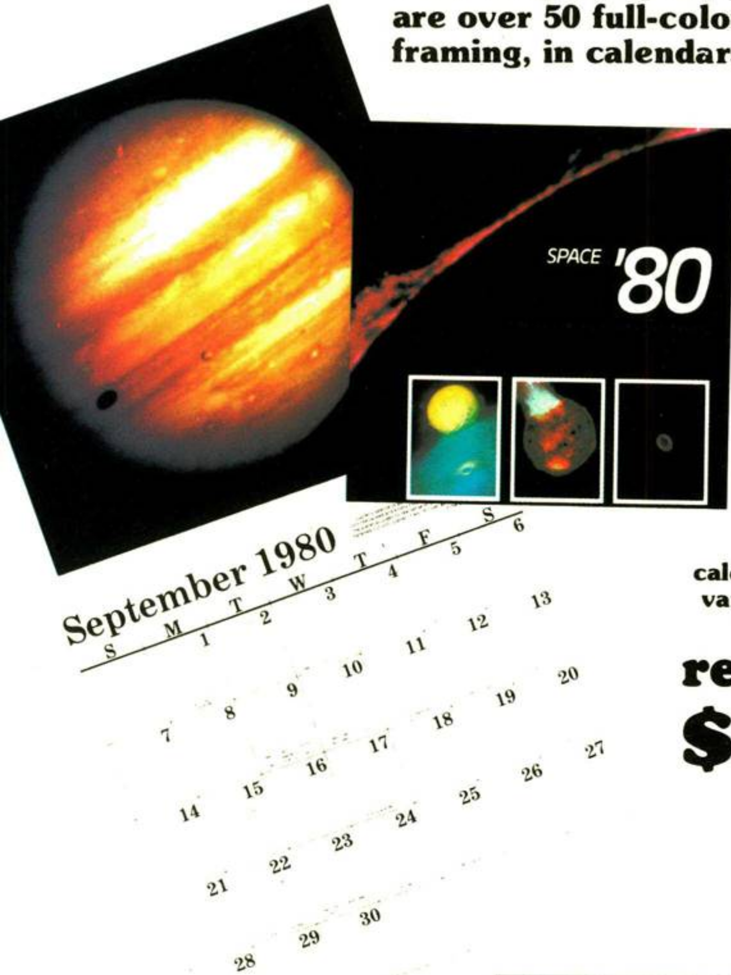
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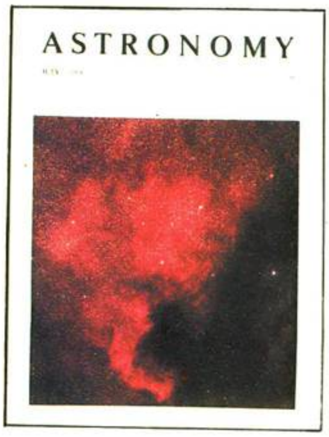

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AstroNews

The Surface of Venus from Pioneer

Based on extensive radar data returned by NASA's Pioneer Venus spacecraft, scientists for the first time have mapped nearly the entire cloud-shrouded planet, and have identified huge continent-size features — including mountains as high as Everest and deep rift valleys.

Venus' surface has never been seen because of the clouds which permanently cover the planet. Pioneer Venus has now mapped about 93 percent of the planet's surface. Prior to Pioneer, less than one percent of Venus' topography had been measured by Earth-based radar.

Pioneer data suggest that Venus' terrain and geology have both strong similarities to — and major differences from — those of any known planet. According to Dr. Harold Masursky, Venus' surface is gently rolling, with local dramatic highs like the North American continent. However, not counting Earth's oceans, Venus' range of elevations is somewhat greater than Earth's, ranging from 2.9 kilometers (9500 feet) below the average radius of Venus' spherical surface to 10.8 kilometers (35,400 feet) above that level.

Pioneer's radar-mapper measured Venus' surface deviations in topography over the entire planet, missing relatively small circular regions at each pole. While the radar on Pioneer can identify differences of elevation of 300 feet, its horizontal resolution is only able to distinguish features many miles wide.

Sixty percent of Venus' surface is relatively flat, rolling plains, varying in height by only 1000 meters (300 feet) between high and low points. This huge, planet-encompassing plain lies at a 6050 kilometer radius from the center of the planet (3751 miles).

About 16 percent of Venus' surface lies below the mean radius defined by the plains. Such low-lying regions as the deep ocean beds are far more common on Earth than on Venus, occupying nearly two-thirds of Earth's surface compared to the one-sixth of Venus.

Most of the remaining 24 percent is only a few thousand feet higher than the plains. Only eight percent of the planet is "true highlands," ranging in height to maximum altitudes of 10.8 kilometers (35,400 feet) above Venus' rolling plains. These true highlands may resemble similar areas on Earth. They may be made of very light rock, and hence "float" much higher than other features.

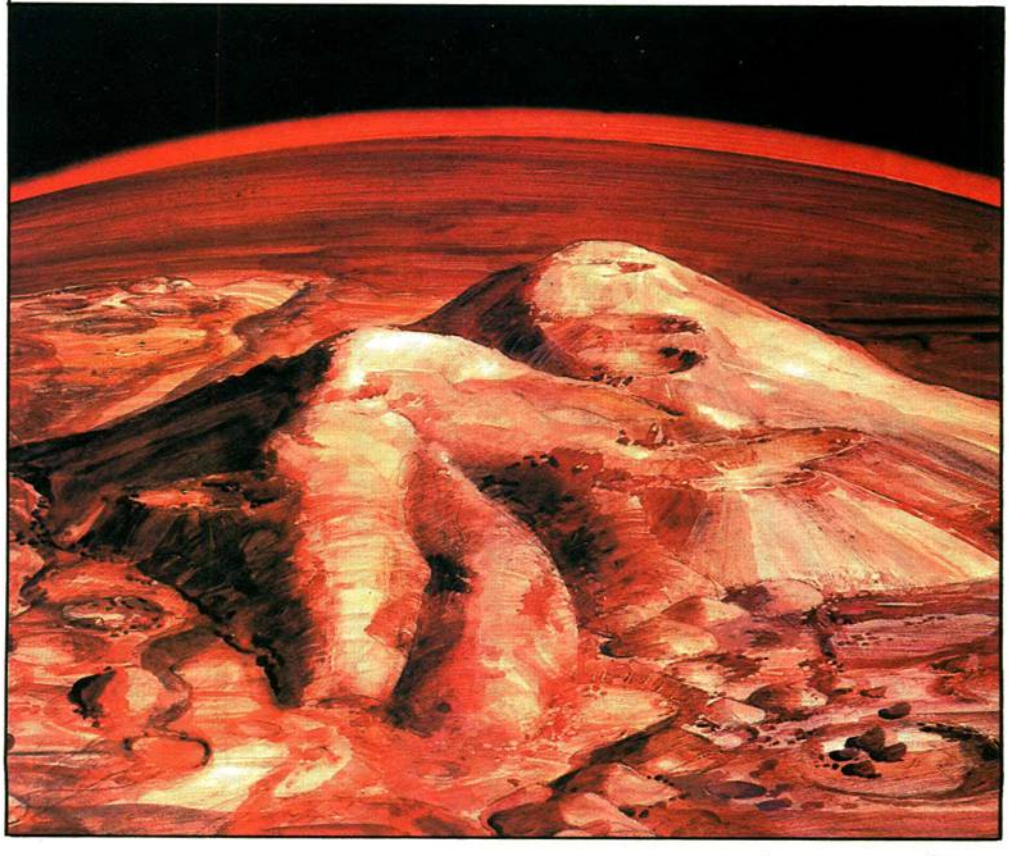
Venusian features have been tentatively named by scientists, pending action by the Working Group on Planetary Nomenclature of the International Astronomical Union. The names chosen, appropriately enough, are largely female — the names of goddesses and heroic women of many civilizations.

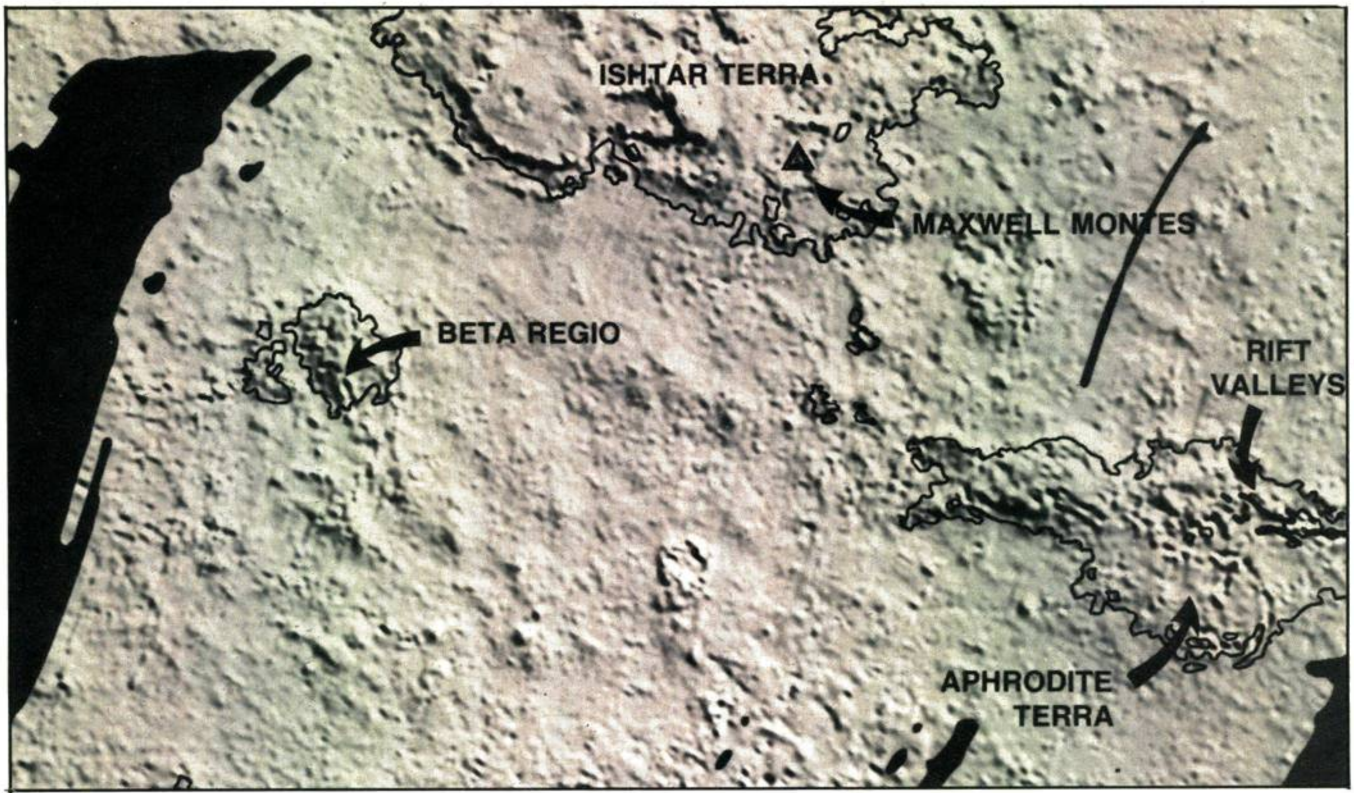
The largest of the highland regions, named *Aphrodite Terra*, is half as large as Africa. The smaller highland region, *Ishtar Terra*, is the size of the continental United States. Both Ishtar and Aphrodite are rough, apparently fractured and faulted. Two other notable highland areas are *Beta Regio*, site of what seem to be two giant shield-shaped volcanos, and *Alpha Regio*, a region of rough, probably geologically old terrain.

Although not as thick as those of Mars and the Moon, it now appears that Venus' crust is thicker than Earth's — so thick that it has choked off most crustal movement or plate tectonics. The lower layer of this crust apparently consists of heavier basalt-type rocks and wraps the entire planet. On top of this is a layer of light, granitic-type continental rock. (Russia's Venera 8 found the radioactivity of rocks in one area of Venus' plains to be like that of granite.) This ancient layer of lighter rocks may form a single huge planet-girdling continent, covering about 84 percent of Venus' total surface. Perched on top of this giant venusian continent are the smaller but still continent-size highland regions.

Venus' crust apparently comprises one huge tectonic plate, compared with Earth's six major plates and several minor ones. Due to continuous formation of new plate material, Earth's plates constantly expand and grind together. Plates which adjoin are forced over and under

Rising up from Venus' great plains, about 30° north of the equator, is Beta Regio—apparently two huge shield volcanos, larger in extent than the Hawaii-Midway chain. Both mountains rise about 13,000 feet above the plains. (The vertical dimension has been exaggerated for clarity.) NASA artwork.





This relief map of Venus, a Mercator projection, shows the principal features identified by Pioneer. *NASA photograph.*

each other — as with the collision of the Indian and Asian plates which pushed up the Himalayas.

On Venus, only about 16 percent of the surface consists of low-lying basins comparable to Earth's ocean basins. There is no evidence of features similar to Earth's midoceanic ridges, where molten basalt wells up to form new crust. On Earth, old crust is carried back into the hot interior by the submergence of one tectonic plate beneath its adjoining plate. Most of Earth's plate boundaries are at the edges of continents, but some are in midocean.

By evolving much more crust than Earth and producing a thick top layer of buoyant material, Venus has squelched plate tectonics, says Dr. William Kaula of the University of California, Los Angeles.

There appear to be abundant primordial impact craters like those on Mars and the Moon scattered over the surface of Venus. These craters have diameters above 75 kilometers (45 miles), large enough for Pioneer to observe. Most of Venus' surface (and hence crust) appears to be ancient terrain. Atmospheric heating, water loss, and crust formation apparently took place in the first 1-2 billion years of the planet's history.

Venus' two continent-size highland areas, Ishtar and Aphrodite, may be remnants of the last plate tectonic collisional zones, before crust formation choked off tectonics completely. Alternatively, they may result from local lifting forces like those that created California's Sierra Nevada range.

The highest and most dramatic continent-size highland region on Venus is the northern highland of Ishtar Terra. It is a high plateau, carrying several mountain ranges. It is about the size of Australia or the continental United States.

The western part of Ishtar (named for the Assyrian goddess of love and war) appears to be a smooth plateau. It is called *Lakshmi Planum* and is about 3300 meters (10,000 feet) above sea level. Lakshmi is bounded on the west and north by mountains ranging upward from 2300 to 3300 meters (7000 to 10,000 feet) above "sea level." The western mountains have been tentatively named *Akna Montes* and the northern range, *Freyja Montes*. The Ishtar plateau is about as high as the Tibetan plateau, but twice as large. The central area of the plateau is smooth in the radar images and may be covered with relatively young lavas. The huge escarpments around the plateau's edge are quite steep.

The highest point yet found on Venus, a mountain massif higher than Everest, has been named *Maxwell Montes*. This huge area of uplifted terrain occupies the entire east end of the Ishtar Terra highlands. Its highest point is 11,800 meters (35,300 feet) above "sea level" and 9000 meters (27,000 feet) above the adjoining Lakshmi plain. The highest parts of the massif run northwest-southeast with lower projections extending both east and west. Observations from both Earth and the Pioneer spacecraft suggest that the mountain region itself is the roughest part of the planet — jumbled terrain, changing abruptly from the smooth plateau west of it. The brightness of this feature indicates that the steep slopes of this Mount Everest of Venus are covered with rocks larger than 10 centimeters (2.5 inches) in diameter.

On the east flank of Maxwell, Pioneer data show a circular 100-kilometer (60-mile) diameter dark feature more than 1000 meters (3000 feet) deep. This may be a volcanic crater. East of Maxwell, extending for 100 degrees of longitude, is a complex topography of ridges and troughs, including many closed basins.

The largest continent-size highland region on Venus has been tentatively named after the Greek goddess Aphrodite. As large as the northern half of Africa, it consists of two mountainous areas separated by a somewhat lower region. Situated almost on Venus' equator, Aphrodite Terra runs almost directly east and west for 9600 kilometers (6000 miles).

Unlike Ishtar, a relatively

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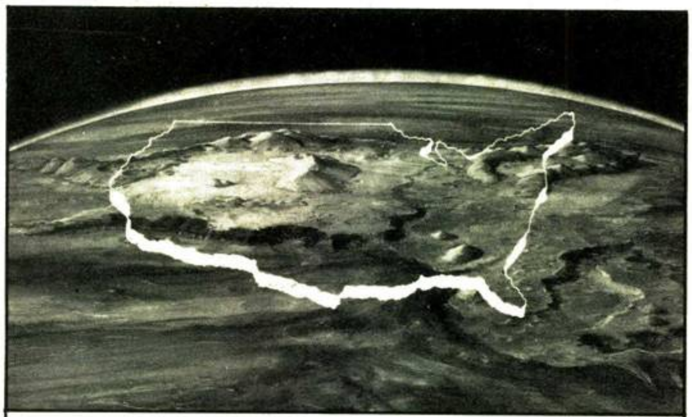


Aphrodite Terra is the largest highland region on Venus. The vertical dimension is exaggerated for clarity. NASA artwork.

level plateau carrying high mountains, the Aphrodite highland region rises to various heights above the mean planet surface. The western mountainous area rises 8000 meters (23,000 feet) above the surrounding terrain, 9000 meters (26,000 feet) above Venus' mean surface. The eastern mountains of Aphrodite rise 3300 meters (10,000 feet) above the surrounding terrain, 4300 meters (13,000 feet) above the mean surface. Like Ishtar, the terrain of these Aphrodite mountains appears to be quite rough. Because Aphrodite does not appear to contain uplifted plateaus or volcanic mountains, Aphrodite may be older and more degraded than Ishtar Terra.

Centered at about 30 degrees north latitude on Venus is Beta Regio, apparently consisting of two huge shield-shaped volcanos, larger than the Hawaii-Midway chain. Beta Regio appears to be situated on a fault line running north and south, from 40 degrees north latitude to 50 degrees south latitude. This long fault zone connects several other highland features, which may be volcanic, south of Beta Regio. The two huge, adjoining mountains (smooth on the surface and shaped like the very wide-based Hawaiian volcanos) cover a north-south distance of about 2100 kilometers (1300 miles). Aside from their appearance, rocks making up the twin Beta mountains appear to be basaltic and hence very likely of volcanic origin. (The Soviet spacecraft Venera 9 and 10 landed just east of Beta, and found the rocks there to have radioactive element concentrations similar to basalts.)

The two shield-shaped mountains making up the Beta region have been named *Theia Mons* (the northern mountain) and the *Rhea Mons* (the southern mountain). Both rise out of Venus' great planet-spanning plains, and both rise to about 4000 meters (13,000 feet) above the plain.

The fourth notable highland feature on Venus is Alpha Regio, a rough region lying about 1800 meters (6000 feet) above the venusian great plain. Alpha Regio is about 25 degrees south of the equator and 6400 kilometers (4000 miles) west of Aphrodite. Radar imaging shows that it has extremely rough terrain with parallel fractures through the whole feature. It may combine old and new geologic forms and resembles the basin and range structure of the western United States.

As noted, a relatively flat, rolling plain covers 60 percent of Venus' surface. Radar imaging shows many circular, dark features with bright central spots on this rolling plain.

These apparent craters with diameters of 400 to 600 kilometers (250 to 320 miles) characteristically have depths of only 200 to 700 meters (650 to 2300 feet). The bright, central areas could be the central peaks, typical of impact craters.

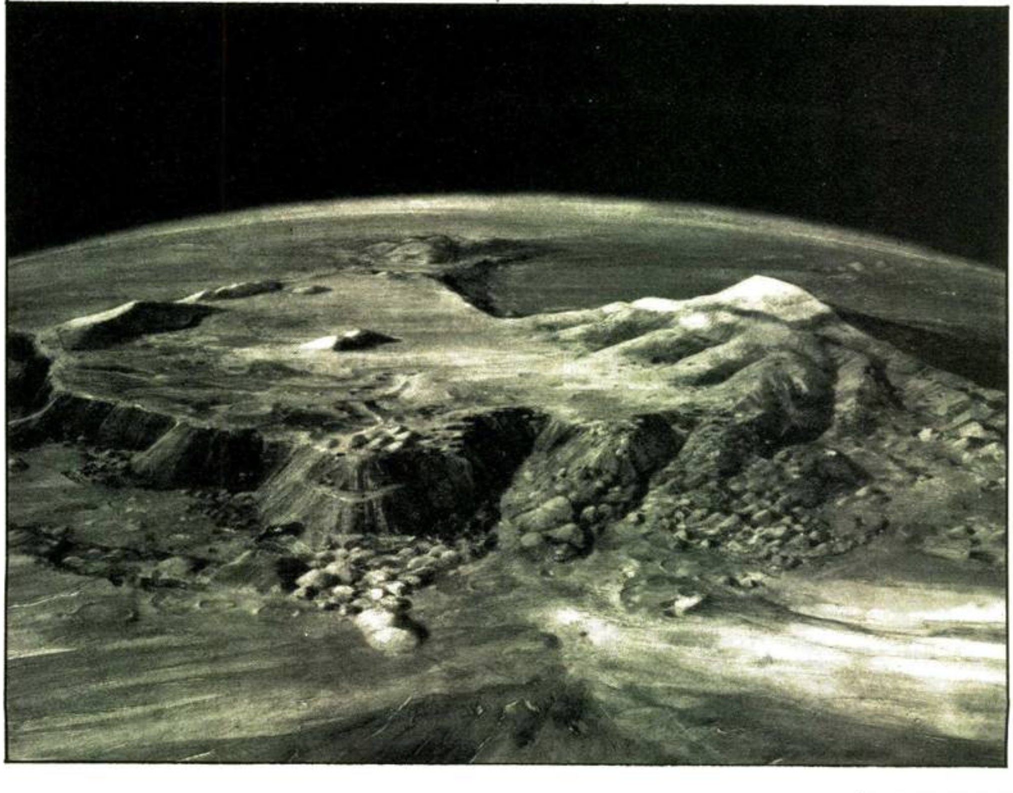
The very small depths and the very large diameters of these apparent craters, compared with the Moon and Mars, can be explained by "surface rebound" like that found on Jupiter's planet-size moons. The apparent widespread cratering suggests that Venus' heavily-cratered ancient crust is preserved over much of the planet.

The largest low area found on Venus so far is centered west of Ishtar at 70 degrees north. At its deepest point, this great basin is about 3000 meters (9,000 feet) below Venus' great plain region. This low area, like others on the planet, is smooth and lacks large crater forms. Like Earth's ocean basins it may be relatively young geologically and filled in by basaltic lava flows. It is about the same size as the North Atlantic ocean basin.

The lowest point on the planet appears to be in the rift valley just east of Aphrodite, slightly lower than the northern hemisphere basin at about 2.9 kilometers (9500 feet) below Venus' mean surface. This trench is deeper than the Dead Sea rift, but only one-fifth the depth of the Marianas trench in the western Pacific. It is roughly the same depth as Vallis Marineris, the great canyon on Mars. While Venus apparently has no plate tectonics, this rift valley and another parallel to it, both in the region east of Aphrodite, seem comparable to the great tectonic rifts on Earth where new rock material wells up out of the molten interior.

In general, the jumbled region east of Aphrodite is characterized by high ridges

The highest and most dramatic continent-sized highland region on Venus is Ishtar Terra, shown here with the vertical dimension exaggerated. Ishtar is a high plateau with mountain ranges. NASA artwork.



and deep valleys. There is a similar region east of Ishtar.

Pioneer Venus has been circling Venus since December 1978, and is still operating well. Another spacecraft, consisting of a carrier bus and four attached probes, arrived at Venus in the same month and penetrated the venusian atmosphere. Together, data from the orbiter and probes are providing the most comprehensive information ever of the phenomena that most visibly set Venus apart from its "sister planet" Earth — its perpetual cloud cover and dense hot atmosphere.

Scientists are hopeful that a planned NASA program, the Venus Orbital Imaging Radar (VOIR) satellite, will be included in the next budget. VOIR, using a synthetic aperture radar system much more sophisticated than the radar aboard Pioneer, will be able to map the entire surface of Venus to a resolution of a few hundred meters (see "Alien Eyes," ASTRONOMY, January 1980). VOIR has been in trouble because of recent budgetary cutbacks.

Scheduling the Shuttle

The latest cargo manifest for the reusable Space Shuttle delays the launch of the first Spacelab mission by another 8 months, splits the International Solar Polar Mission, and eliminates recovery of the Solar Maximum Mission satellite.

The new schedule was announced on May 29 following a Shuttle Users Conference held at the Kennedy Space Center in Florida. A total of 79 missions is on the schedule, which starts with the first Shuttle test flight and runs through September 1986. 124 different payloads are included on those missions. They are equivalent to 20 Spacelab missions, 16 missions with upper stages (mostly commercial), 25 military missions, 4½ NASA or other government free flyers, 4 planetary missions, and 6 reflights or missions of opportunity. Overall load factor is better than 90 percent.

Delays and problems in the Shuttle's development program have forced NASA officially to reset the first launch for March 1981 and the first operational flight (designated STS-5) for September 1982. That flight will carry the first Tracking and Data Relay Satellite (TDRS) which, with TDRS-B, is essential to the intense Spacelab missions that will outstrip the Shuttle's onboard recording capacity.

Here is a summary of the new schedule:

- **Planetary missions**: Galileo is still planned for February and March of 1984. The mission was split earlier because of weight problems. The probe will be launched first (STS-18), followed by the orbiter (STS-19). The International Solar Polar Mission is delayed 2 years as a result of this spring's budget cuts. The probes have been separated because the delay increases the energy required. The first will be launched in March 1985 (STS-35) with the second following in April (STS-36).
- **Free Flyers**: Only three science satellites are manifested. (1) The Active Magnetospheric Particle Tracer Experiment (AMPTE) will be launched in August 1984 (STS-26) on a mission that also carries two communications satellites. AMPTE will make use of the Delta-class spinning solid fuel upper stage. (2) The Gamma Ray Observatory will fly in June 1985 on STS-39, a mission shared by a single science pallet, Intelsat IV-5. (3) The Cosmic Background Explorer (COBE) will be launched in July (STS-4w) on a polar-orbit mission with a single science pallet.
- The **Space Telescope** will fly in January 1984 (STS-16), a one-month delay from the previous schedule.
- The **Extreme Ultraviolet Explorer** will be launched on STS-52 in January 1986.

In addition, NASA has two missions, STS-6w in December 1985 and STS-8w in April 1986, set aside as undesignated NASA free flyers in hopes that new start funding will be found for projects that have been delayed.

A total of 16 "dedicated" Spacelab missions is planned, 14 U.S. and 2 West German. (Dedicated missions are those that use the entire payload bay.) Only space science missions are given in the accompanying table, and by flight order rather than Spacelab numbers which have been juggled by funding.

In addition to the Spacelab missions, there are six flights that will carry a single pallet allocated to space science experiments: STS-4 (already filled with solar physics instruments), STS-24 (July 1984), STS-32 (February 1985), STS-4w (July 1985), STS-52 (January 1986), and STS-58 (April 1986). There is also an undesignated pallet opportunity on STS-56 (March 1986).

Retrieval of the Solar Maximum Mission, the first Shuttle serviceable satellite, had been planned for STS-12 in December 1982 on the old schedule, but this has been dropped altogether. Retrieval had been tied to deployment of the Long Duration Exposure Facility (LDEF), now STS-29, in November 1984, because both require use of additional maneuvering fuel to get the Shuttle to higher orbit. By the time LDEF is flown, Solar Max will have reentered the atmosphere. However, NASA hopes that the schedule will open up enough to allow retrieval on STS-8 in March 1983, a communications satellite mission.

This latest announced schedule, of course, is subject to further change and delay depending on current Shuttle testing and development.

Spacelab Missions

Flight Number		Date of Launch		Mission
Spacelab 1	STS-10	May	1983	checkout, some astronomy and solar physics
Spacelab 2	STS-14	Nov	1983	solar and stellar physics
Spacelab 4	STS-22	May	1984	life sciences
Spacelab 6	STS-30	Dec	1984	solar-terrestrial physics
Spacelab 5	STS-34	Mar	1985	astrophysics
Spacelab D4	STS-40	Jul	1985	astrophysics (West Germany)
Spacelab 10	STS-48	Nov	1985	life sciences
Spacelab 16	STS-51	Jan	1986	solar physics, 1.2 meter solar telescope
Spacelab 9	STS-60	May	1986	astronomy
Spacelab 11	STS-10w	Aug	1986	space plasma mission from Vandenberg
Spacelab 15	STS-66	Aug	1986	life sciences

A Day on Saturn

A team of scientists working for NASA has determined that the rotation period of Saturn — the length of the planet's day — is some 25 minutes longer than had been previously estimated.

Using bursts of radio noise from Saturn recorded by the two Voyager spacecraft, the length of one day was determined to be 10 hours 39.9 minutes long. Previously, astronomers using Earth-based observations of the ringed planet had found the length of a saturnian day to be about 10 hours 15 minutes, but admitted their measurements lacked great accuracy.

This lack of accuracy was due in part to the fact that Saturn does not have a solid surface. Observers can see only the tops of the planet's clouds, which have no sharply defined features to allow an accurate determination of the rotation period.

The new value for the length of a saturnian day was made by Michael Kaiser and Michael Desch of NASA's Goddard Space Fight Center in Greenbelt, Maryland, and James Warwick and Jeffrey Pearce of Radiophysics, Inc., Boulder, Colorado. They are members of the Voyager Planetary Radio Astronomy team headed by Warwick. Dr. Warwick's team recorded

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radio signals from a variety of sources in the sky during January 1980, when Voyager 1 was more than 380 million kilometers (236 million miles) from Saturn, and Voyager 2 was more than 554 million km (344 million miles) from the planet.

By gradually eliminating signals coming from the Sun, Jupiter, and other sources, the investigators determined that the signals they were receiving every 10 hours 39.9 minutes originated at the north pole of Saturn and were precisely controlled by the planet's rotating magnetic field.

Several years ago Earth-bound radio astronomers were able to pin down the rotation rate of Jupiter using the same method. But this method was not possible for Saturn from Earth because of the weakness of Saturn's radio emissions. Although Earth, Jupiter, and Saturn are all emitters of radio signals, scientists do not as yet understand how these signals are generated.

Voyager 1 is scheduled to make its closest approach to Saturn on November 12 of this year, while Voyager 2 will pass the planet on August 25, 1981.

Shuttle Student Project

NASA has selected the National Science Teachers Association (NSTA) for negotiation of a contract to manage the Shuttle Student Involvement Project. The project is a nationwide competition to be conducted annually among secondary students for scientific and engineering experiments to be performed on a "space available" basis aboard the Shuttle. The Space Shuttle is expected to be operational in 1982.

NASA Administrator Dr. Robert A. Frosch said, "The vitality of NASA depends heavily on an infusion of fresh ideas. Therefore, our connection with students is extremely valuable to us and is an important part of our program."

The program is expected to cost $273,000 for the approximately 30-month duration of the contract. The competition will be conducted in the fall of each year, leading to the selection of winners the following spring.

NSTA will formulate rules for the competition and define 10 regions from which semifinalists will be selected. It will also distribute announcements, devise the entry/application forms and project rules, and manage the actual competition. The group will work closely with Dr. Glen Wilson, NASA special assistant for student activities, in formulating rules and selecting winning entries.

Twenty semifinalists will be chosen in each of the 10 regions. Each region will hold a seminar at which semifinalists will discuss their proposals. Following these, up to 10 proposals in each region will be chosen for final judging. The 10 final winners will be named from the pool of approximately 100 regional choices. NASA retains final decision on whether it is possible to fly a particular experiment or accommodate winning students in some other fashion.

Student winners may also receive other awards such as a trip to Kennedy Space Center in Florida, to discuss their projects with other students, professional scientists and NASA officials.

A Solar Ultraviolet Monitor

A team of space scientists at the Naval Research Laboratory (NRL) is developing a unique Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) that is planned for use aboard the Space Shuttle to obtain a deeper insight into solar activity. NRL's Dr. Guenter E. Brueckner, principal investigator in the research, says SUSIM will be used aboard the Space Shuttle to study long-term variations of solar fluxes to understand more clearly and monitor more accurately the ultraviolet radiation emitted from the Sun's chromosphere and corona.

"The Sun's radiation is absorbed by the Earth's atmosphere and induces photochemical reactions. Therefore, a better knowledge of the Sun's output, through the use of SUSIM, will lead us to more complete understanding of the relationship between solar and terrestrial phenomena," he reports. "Measurements done in the 120 to 400 nanometer [1 nanometer = 10 Angstroms] wavelength range by conventional methods have thus far not been accurate enough for scientists to establish credible values for long-term variations of the solar flux," explains Brueckner.

Solar radiation in the wavelength interval to be studied by SUSIM controls many of the photochemical processes in the Earth's atmosphere at altitudes below 1 kilometer. Thus, variations in this radiation can alter the composition of the lower atmosphere, affecting, among other things, the lifetime of pollutants and ion density in the D-region of the ionosphere. In addition, the D-region of the ionosphere is important to the Navy because it has a direct effect on communications systems.

Initially, SUSIM is expected to be used on an early flight of the orbiter, OSS-1, as a solar sensor. The pilot of the spacecraft will use SUSIM's real-time data to point the instrument cluster directly at the Sun where scientific instruments will monitor the entire solar disk to measure the variation of its intensity with solar activity.

There are three NRL scientists on Brueckner's research team, Michael E. Van Hoosier, Dr. Dianne K. Prinz, and Dr. John-David F. Bartoe, who are presently developing and testing the sensors for the Space Shuttle flight. Both Prinz and Bartoe have been selected as candidates for a Space Shuttle flight; one of them may be chosen to fly a scientific mission to obtain first-hand data on the Sun's activity through the use of their scientific instruments.

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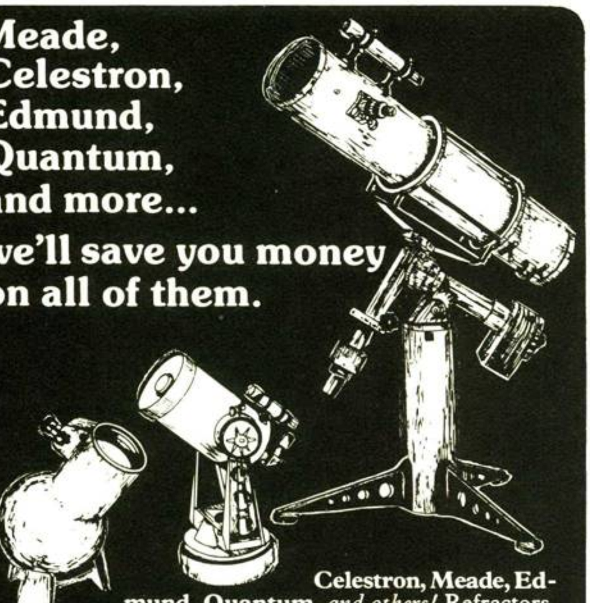

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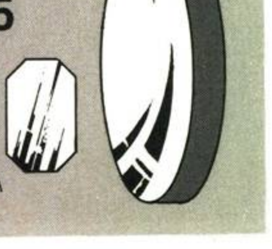

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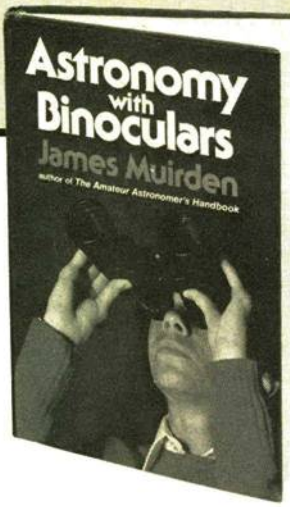
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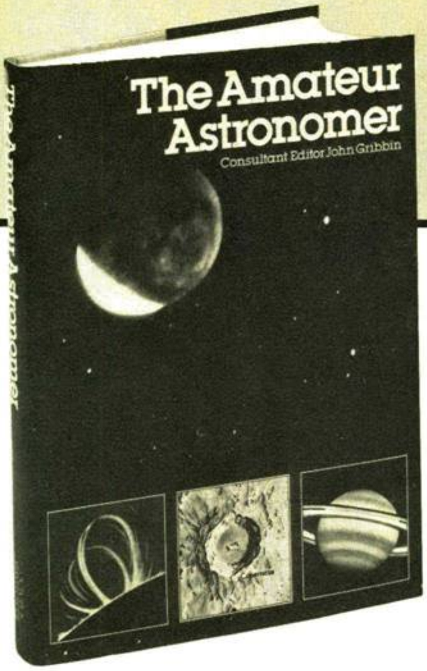

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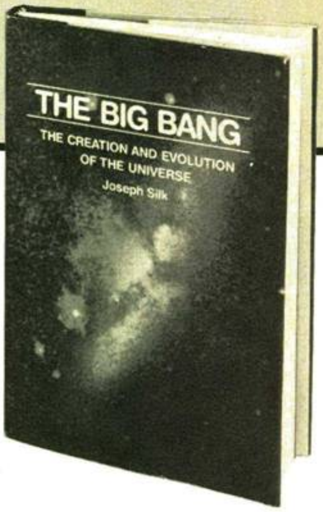

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Because Questar's inventor loved fine instruments, he designed Questar for himself. He had begun dreaming about the kind of telescope he someday wanted to own, long before such a thing was considered a possibility.

To begin with, of course, there was to be a set of optics so fine that no amount of money, time, or human effort could improve upon it. Second, since he believed that the use of a telescope should not be a difficult physical chore, the size was extremely important: it should be easily portable. Preferably it would be small enough to be used on a table, where a person could sit in a relaxed position to observe and be able to have a writing surface at hand. And since he planned to carry it in his travels, it would be packaged handsomely in a piece of leather luggage.

Third, the accessories which were necessary for the enjoyment of a telescope were to be built in and should have fingertip controls within easy reach.

Fourth, the mechanical design must incorporate a means of putting the telescope into its polar equatorial position at a moment's notice and without the need of a separate tripod.

Fifth, the versatility that he visualized would make this instrument equally suitable for nature studies in the field. It also should be able to focus on close objects, which no other telescope in the world could do.

Sixth, the design must be photovisual so that he could record on film whatever these superior optics would present to the eye.

And finally, the instrument must be of rugged construction and vibrationless, without the aggravating oscillations of long-tubed conventional telescopes.

* * *

As we have said, this was the dream, but one lacking the possibility of fulfillment within the state of the art at that time. However, in the 1940's an important discovery in optics occurred. When Maksutov published, in the *Journal of the Optical Society of America,* a paper on his mixed lens-mirror, or catadioptric, system, it was immediately apparent to Questar's designer, Lawrence Braymer, that this break-through in optics would make possible a miniaturized version of the astronomical telescope which he had for so long wanted to build.

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Most remarkable of all were the optics—this was a system so fine that it has consistently delivered resolution surpassing its theoretical limits. Throughout its subsequent history, the care and precision with which every set of optics has been made and star tested has earned for the Questar telescope its reputation as the finest in the world.

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Extraterrestrial Climate Threats

by David H. Clark

What's ahead for us? What sort of climate is in store as planet Earth enters the third millennium? In the short term, over a time scale of decades or centuries, the greatest threats to climate may be manmade — for example, deforestation or burning of fossil fuels. Yet another short-term threat is our seemingly insatiable hunger for energy. All energy we generate finally ends up as heat released to the oceans and atmosphere. If such thermal pollution were to increase at its present rate for just a hundred years, it would be sufficient to increase the average global temperature by about 3/4° C and initiate melting of the polar ice caps. Localized effects may occur sooner — for example, it's been estimated that in just 30 years the heat released in the Los Angeles basin through energy consumption will be 18% of the normal incident solar energy of that area.

With humans seemingly set on a course destined to destroy the environment and cause a major climatic catastrophe, it might seem rather pointless to investigate extraterrestrial phenomena that could produce an even more horrific impact. Nevertheless, scientists have considered the problem, principally in the context of extraterrestrial influences on the Earth's climatic history but also with a concern for future climate.

How could extraterrestrial phenomena possibly change our climate? Research shows several ways, each unpleasantness having a greater or lesser degree of probability. They include changes in the Sun's output, the amount of light received at Earth, the reflectivity of Earth itself, or even direct modifications of the air we breathe. Most would affect Earth's life forms, either outright or via forced climatic change.

Nor do they complete the list: other events have affected Earth's geological history. For example, it has been suggested that the impact of asteroids early in geohistory, several billion years ago, may have created the ocean basins. Earth-crossing asteroids still exist today and an encounter with one would be catastrophic, to say the least.

The Black Clouds

But let's shift our view outside the confines of the solar system and look at the Galaxy as a whole. You're probably familiar with photos of galaxies that show spiral structures of intertwined arms. (Our Milky Way is believed to be one of those galaxies having a spiral structure.) Within the arms lie the majority of the bright stars. But a spiral galaxy contains not only stars, but also giant "clouds" of gas and dust. The stars and interstellar clouds all revolve about the center of the galaxy, like a colossal catherine wheel. What would happen if we were to collide with one of the Galaxy's immense dust clouds?

Our solar system lies close to the outer periphery of the Milky Way, about three hundred million billion kilometers from the galactic center. At this distance, it takes us about 200 million years to complete one revolution, an interval known as the *galactic year*. Astronomers predict several collisions of the solar system with interstellar clouds during such an interval. Indeed, there's one such cloud at an estimated distance of about one thousand billion kilometers. In astronomical terms this cloud is relatively nearby, although it will be ten thousand years at the very least before the solar system experiences its dusty embrace.

The impact of a comet — even a small one — would have ghastly consequences for life on Earth. Creatures that survived destruction by the initial blast would face climate changes from the effects of injecting large quantities of material (rock powder and water vapor) into the stratosphere. These materials would decrease the amount of sunlight reaching the Earth's surface, likely triggering a deep and long-lasting ice age. Painting by Paul Hudson.

Exactly how an encounter with an interstellar cloud would affect climate remains uncertain. Cloud material falling onto the Sun could cause it to brighten and radiate more energy. The Sun of course powers Earth's climatic system, so increasing its radiation would profoundly influence our climate for the worse. Warming the surface would melt ice caps and flood the populous continental margins. Weather systems and the crops dependent on them would be disarrayed.

Then, on the other hand, it could work in reverse. Shielding Earth from the Sun's stream of radiation might easily be worse. The higher latitudes would become uninhabitable; glaciers would begin to move toward equatorial regions; human societies would be in general upheaval. Astronomer Fred Hoyle wrote a terrifying SF novel, *The Black Cloud*, on this very theme.

How Constant Is the Solar Constant?

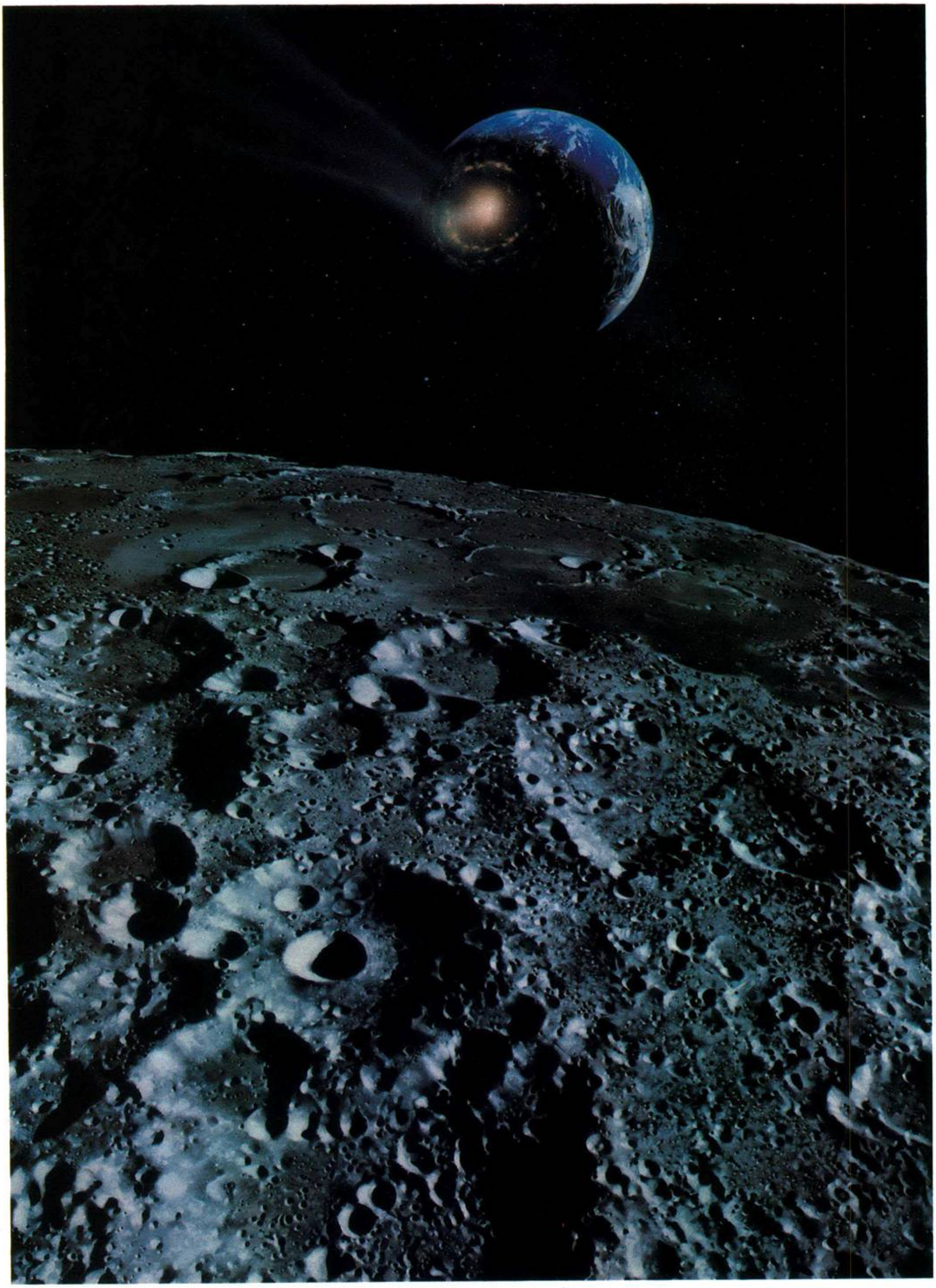
But even simpler still, could the solar "constant" (the energy received above the atmosphere from the Sun) itself show a variation over a time scale of just decades? Until recently solar astronomers would have dismissed such a possibility out-of-hand. There's no question that on very long time scales (hundreds and thousands of millions of years) the internal workings of the Sun vary so that pronounced changes in its brightness occur. However, over short intervals the only evidence of variability on the Sun seems to be in the occurrence of sunspots. These dark spots on the face of the Sun are about two thousand degrees cooler than the 6000° region surrounding them.

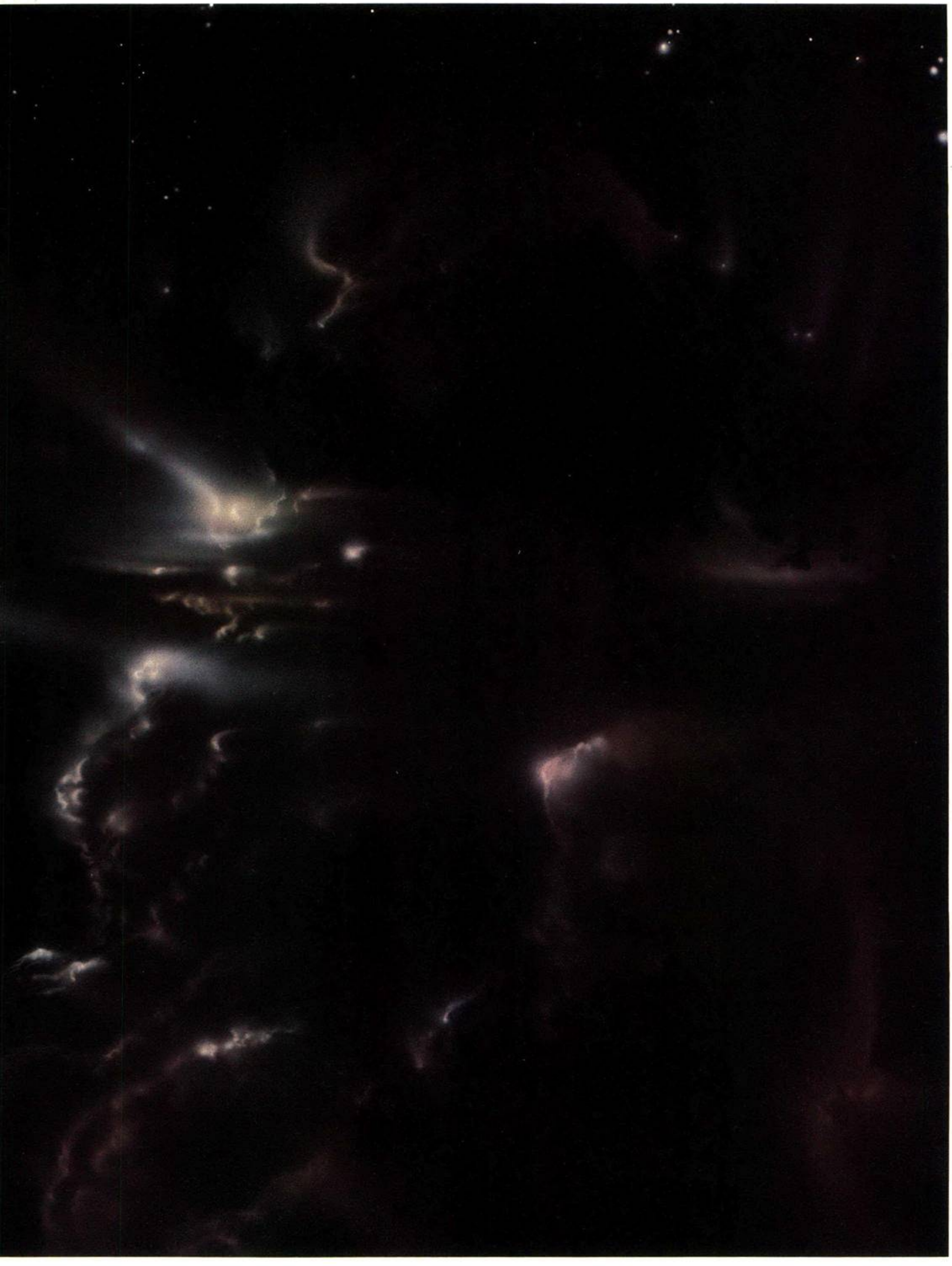
Sunspots have been recorded since antiquity, although their discovery is often falsely attributed to Galileo, who merely confirmed their nature with his early telescopic observations. The frequency of sunspots waxes and wanes over an approximate 11-year period. This cycle was long-believed to be an enduring feature of solar behavior, although Walter Maunder argued at the end of the 19th century that historical observations showed sunspots were almost totally absent during much of the 17th century (see "A New Revolution in Solar Physics," ASTRONOMY, February 1979).

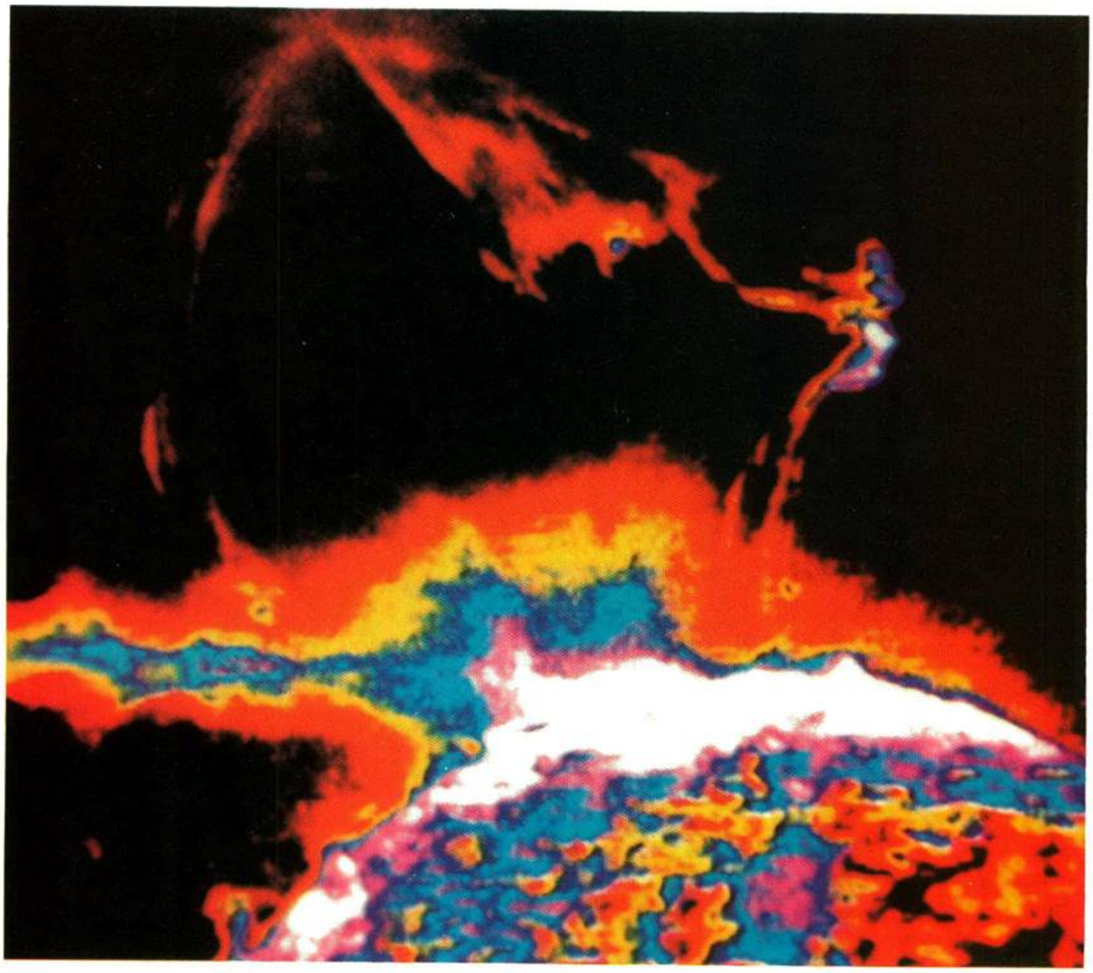
A few years ago Jack Eddy (in the United States) completed analyzing historical records and other indicators of solar variability to confirm that the absence of sunspots from about 1640 to 1700 was indeed real. This interval is now known as the *Maunder Minimum*, in recognition of his pioneer efforts. Other intervals when sunspots essentially disappeared have now been identified from historical records, chiefly oriental.

The Maunder Minimum coincides with the "Little Ice Age" when mean global temperature dropped appreciably for many decades. Although the Maunder Minimum was

Overleaf: We all know how essential the warm glow of the Sun is for our continued existence; fewer people know just how delicate the balance is. If the Sun's radiation were a few percent stronger or weaker, life would become much more difficult. Here we see a dense interstellar dust cloud about to engulf the Earth. It might make the Sun flare up — or it could decrease its warmth drastically. Painting by Mark Paternostro.







Active solar prominences (seen here in a photo taken from Skylab) accompany intense solar flares and spew out tendrils of hot gas tens of thousands of miles from the Sun's surface. Flares can occur at any time, but become stronger and more frequent in step with the sunspot cycle. Depending on its strength, a "mega-flare" could affect the Earth's atmosphere, either through photochemical changes or by forced heating. Photo by NASA.

initially doubted, there never had been any question of the Little Ice Age's reality. Climatologists possess substantial written records that recount the severity of the climate, as well as other, more indirect, evidence.

The coincidence of the Maunder Minimum and the Little Ice Age has proven to be the key firmly linking long-term sunspot behavior with climate. Other periods where sunspots were either virtually absent or unusually profuse coincide with anomalous climatic behavior. Just how this link between sunspots and climate operates remains uncertain. However, subtle changes in the solar constant could affect the occurrence of sunspots as well as climate.

In view of the social and economic consequences of climatic variations induced by a variable Sun, high-precision monitoring of the Sun's energy output surely represents one of the most important experimental challenges facing contemporary science.

Orbits Are Forever?

What would happen if the shape of the Earth's orbit around the Sun varied? It is elliptical in shape, but because of the gravitational attraction of the Sun and Moon on the oblate figure of the Earth, and the varying gravitational effects of the other planets, the elements of its orbit and its attitude with reference to the Sun are constantly changing.

For example, the direction of the Earth's spin axis in space slowly varies over a period of about 26,000 years, and the shape of the elliptical orbit (its distortion from a circle) varies on a time scale of about 100,000 years. These variations in the Earth's orbit about the Sun don't alter significantly the total solar radiation reaching the Earth's surface. They do, however, change the insolation — that is, the amount of heat reaching different latitudes at different times of the year — and this can alter the climate.

It now seems certain that changes in the Earth's orbit have been the fundamental cause of climatic variations over the past few hundred thousand years — intervals of cold more severe than the Little Ice Age and lasting for a few tens of thousands of years, but not major ice epochs. The Earth in future millennia *will* suffer similar changes; they're inescapable.

Collisions with Comets?

In recent years astronomers Fred Hoyle and Chandra Wickramasinghe have proposed that Earth's early life forms had an extraterrestrial origin in prebiotic molecules from interstellar space. According to their hypothesis, these reached Earth some 4 billion years ago through the impact of a comet-type body.

This theory, in fact, is an updated version of the 19th century "panspermia hypothesis" in which microorganisms from interstellar space were blown from planet to planet by the pressure of starlight. The conventional — and admittedly far more likely — theory gives life a wholly terrestrial origin in a "primordial soup." But Hoyle and Wickramasinghe's cometary encounter proposal goes beyond the mere origin of life — even today, they argue, continuing influxes of cometary debris bring viruses responsible for diseases of plants and animals.

Collisions with comets, like the aforementioned collisions with asteroids, are then a possible cause of catastrophes. Even an all-out collision isn't needed; if the Earth passed through the dust tail of a comet, particles from it could impact the upper atmosphere in vast quantities — depositing perhaps about 100 million tons (about 1/1000 the mass of a typical comet) in small particles of highly reflective material.

For a decade or more this screen of cometary dust could partially or wholly shield the Earth's surface from sunlight. Reflecting a large fraction of solar energy back into space wouldn't cool the Earth instantaneously because of the enormous heat content of the oceans. But soon a standing temperature difference would develop between warm seas and cooling landmasses that could drive continuous 100-mph gales.

Temperate zones would soon become arctic and tropical zones temperate; ice caps would advance. And although the blanket of shielding cometary dust is short-lived and would gradually settle out over the Earth's surface, the planet would not likely return to its former condition. Why not? Since ice sheets themselves are whitely reflective, they would ensure that the Earth would also remain so — and cold.

What's scary is that the process is nearly irreversible. Only drastically reducing the ice caps' reflectivity, perhaps with volcanic activity dirtying them, or orbital elements changing to bring us nearer the Sun could break the self-reinforcing cycle. Mars appears to undergo this sort of thing regularly, having only long-term orbital shifts to loosen the martian ice ages' chilly grip.

Statistics can provide an estimate of the likelihood of Earth's colliding with a comet. It turns out to be disturbingly high — perhaps a collision as often as every 10 to 100 million years on average. This certainly isn't often enough to cause alarm, but is sufficient to explain some of the major ice epochs. One theory suggests that a comet collision was responsible for the sudden extinction of a great many land and ocean species some 65 million years ago. The cause of this so-called *terminal Cretaceous event* is still unknown. Perhaps as the ancients claimed, comets may indeed be harbingers of doom.

Exploding Stellar Neighbors?

What about nearby stars? Could one of them "go supernova" and harm us? Supernovae are the violent end to the evolution of certain types of stars. The energy released in these cataclysmic acts is almost beyond comprehension — equivalent to the simultaneous energy release from about ten billion, billion, billion ten-megaton hydrogen bombs! The outer envelope of the exploding star is ejected with velocities of thousands of kilometers per second.

Supernovae occur within the observable universe at a rate of more than 10 every second. Within the Milky Way, a supernova occurs about every 20 to 30 years on average, although perhaps only one every 50 million years is close by enough for the expanding ejecta of the exploded star to engulf the Earth.

Such an interval between nearby supernovae might seem so long as to be of minimal concern, especially since there is no star presently nearby which could explode as a supernova. But measured against the extreme age of the solar system, such events are relatively frequent, having occurred perhaps a hundred times since the birth of the solar system. Supernovae probably detonate close enough to Earth sufficiently often to have had an influence on its evolutionary history and will likely continue to exert sporadic influence into the future.

What could the global impact of a nearby supernova be? Certainly such an outburst would be an extremely brilliant spectacle. But could its influence extend beyond astonishment, bewildered curiosity, and admiration on the part of those who observed it?

One possible mechanism by which a supernova could affect the Earth accompanies the explosion itself, when about one hundredth of one per cent of the energy is contained in a short-duration blast of X-rays. Following this comes the expanding cloud of ejecta from the explosion, which might reach Earth centuries or millennia after the X-ray burst.

Most of either would be absorbed almost completely in the upper atmosphere, so their direct impact at the surface would be minimal. But their influence on the chemistry of the upper atmosphere should be significant. X-ray bursts or energetic particles cause nitrogen, a constituent of the upper atmosphere, to combine with oxygen to form nitric oxides. A nitric oxide smog could partially shield the Earth from incident radiation from the Sun, with an impact on climate similar to the "runaway glaciation" accompanying a cometary collision. In addition, increasing the concentration of atmospheric nitric oxides (usually present only in very small amounts) leads to the destruction of the Earth's protective ozone layer.

Ozone is molecular oxygen in which each molecule contains three oxygen atoms rather than the two of normal molecular oxygen. It is familiar to most people as a gas with a particularly pungent smell, formed by the action of electrical discharge — the first indication that a piece of electrical equipment may be faulty is often given by the smell of ozone.

The ozone layer filters out ultraviolet radiation from the Sun almost totally. For at least as long as the Earth has had such a protective ozone layer, life has evolved protected from the solar ultraviolet radiation, so that any increase in intensity may have profound significance for living systems.

The genetic information of life is stored in the complex helical chain molecule DNA; strong ultraviolet radiation destroys DNA's essential structure. Nature allows for an acceptable "spontaneous" mutation rate in genetic information, and indeed such mutations have made some adaptions to environmental changes possible. Nevertheless, a sudden change in the level of ultraviolet radiation following the destruction of the ozone layer by a nearby supernova would probably cause a mutation rate few living species could accommodate.

Climate also would be disturbed. Since absorption of solar ultraviolet radiation in the ozone layer is an important mechanism for heating the stratosphere, its temporary destruction would remove the heat source. The temperature at the Earth's surface would subsequently drop a little to complement the cooling resulting from the nitric oxide smog and both would accentuate the drift into major climatic change.

Massive Solar Flares?

Though well within the realm of probability, all these dire effects seem pretty remote. Are there any phenomena operating *right now* that could disrupt the climate, for example, a giant solar flare?

Solar flares are tongues of hot gas violently ejected from the Sun's surface, a portion of which eventually reaches the Earth's upper atmosphere as a stream of energetic particles superimposed on the solar wind. These occur relatively frequently, especially in years of peak sunspot activity (like 1980). They are known to modify the upper atmosphere in ways that result in global radio communication being temporarily blacked out.

Some scientists have argued that giant solar flares, 100 to 1000 times more energetic than anything seen in historical times, might exist; these would have similar biological and climatic impact to that of a nearby supernova. However, since we haven't yet any firm evidence that the Sun could have (or has had) such spectacular flare activity, here the matter must rest.

In an era of energy crises and concern for the short-term climatic effects of thermal pollution, dwelling on long-term climatic probabilities may seem like sensationalist doomsday-mongering. But let's not narrow our focus too much: if the past is any guide at all, there's no reason to suppose that all our planet's climatic upheavals are over. Far from it; what now reads like academic fantasy-spinning is very likely someday to be somebody's reality.

David H. Clark is at the Royal Greenwich Observatory. He is co-author of "A New Revolution in Solar Astronomy" (ASTRONOMY, February 1979) and the book **The Historical Supernovae**.

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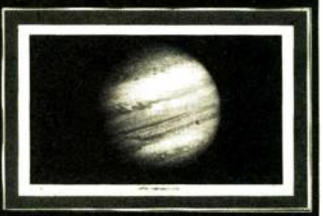

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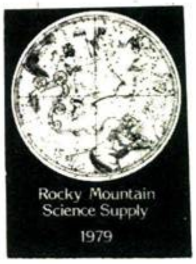

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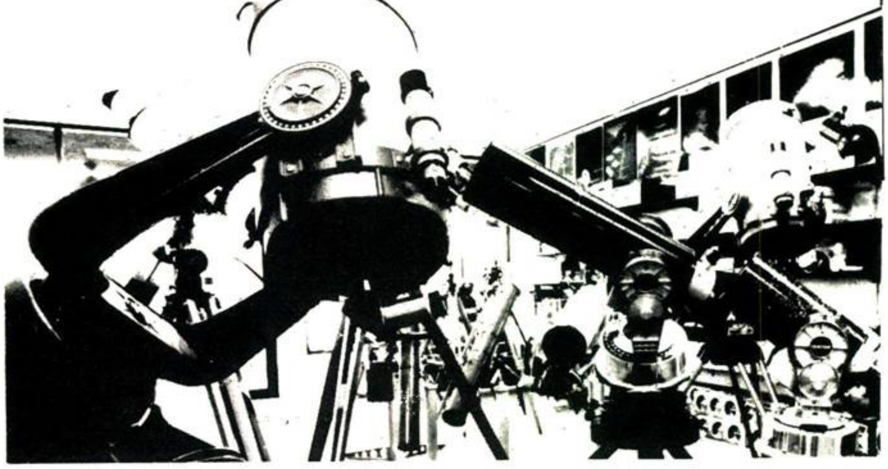

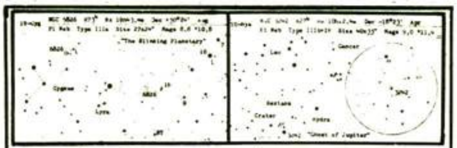

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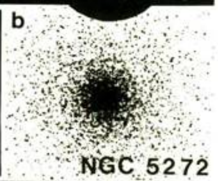

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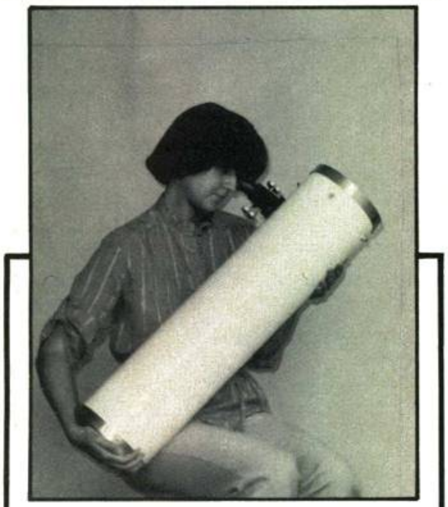

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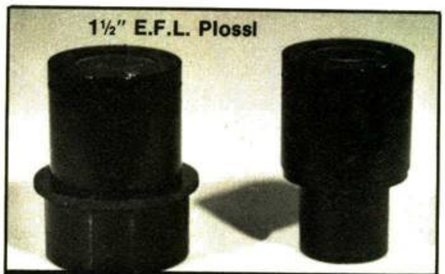

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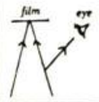

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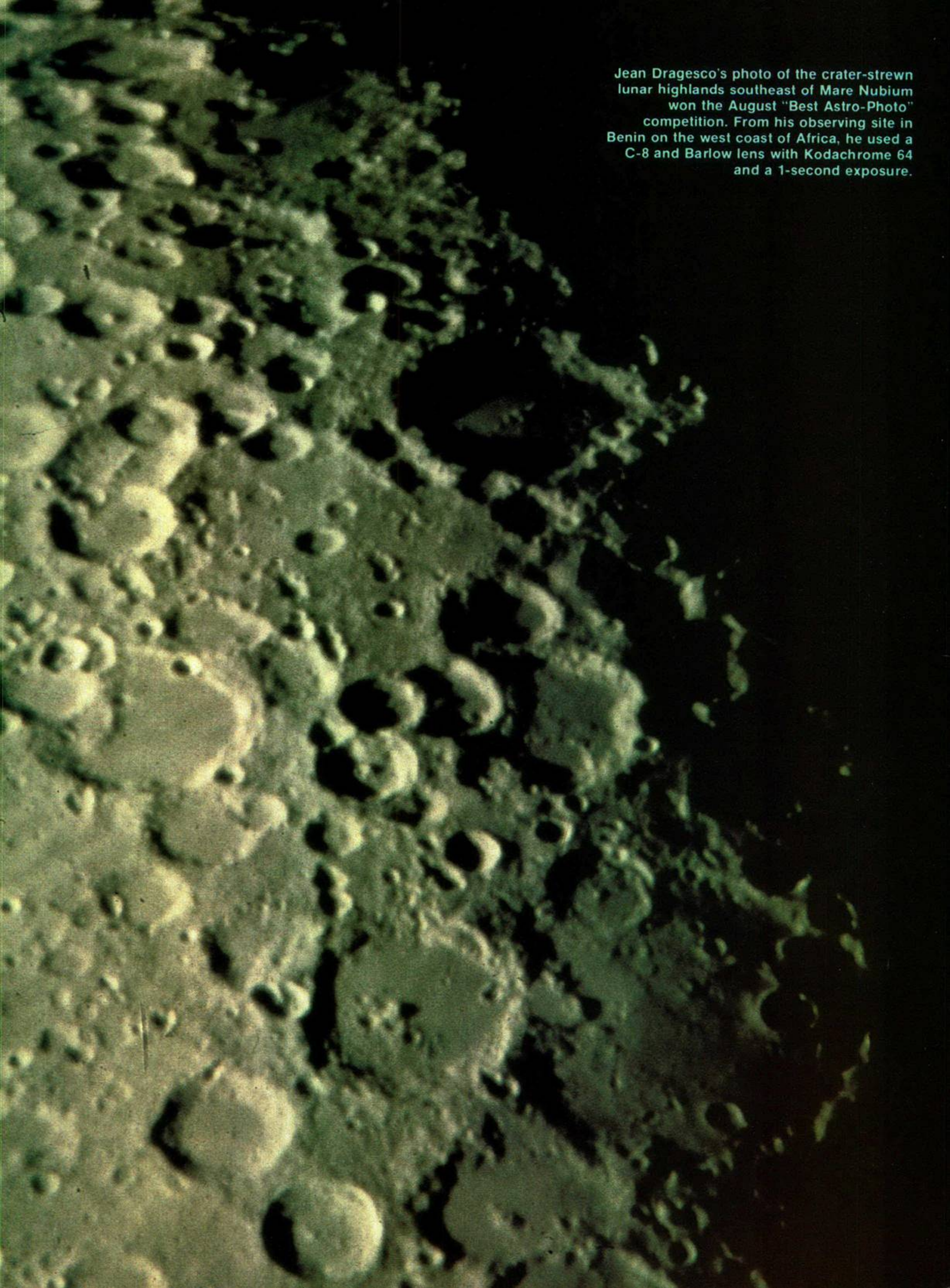


Jean Dragesco's photo of the crater-strewn lunar highlands southeast of Mare Nubium won the August "Best Astro-Photo" competition. From his observing site in Benin on the west coast of Africa, he used a C-8 and Barlow lens with Kodachrome 64 and a 1-second exposure.

close-up on aquila

through the eyepiece

This August signals the disappearance of Jupiter from the evening skies, with Saturn to follow next month. Mars is still around, but hardly worth the trouble, while Mercury and Venus both grace the mornings. Last, and by no means least, we'll see a fine return of the annual Perseid meteors.

Mercury

The second half of Mercury's 4-week morning apparition comes this month. Greatest elongation is on the 1st (at 2^h UT); highest elevation over the eastern horizon comes two days later, but since this'll amount to only 8° (45 minutes before sunrise), the elongation won't be a very striking one.

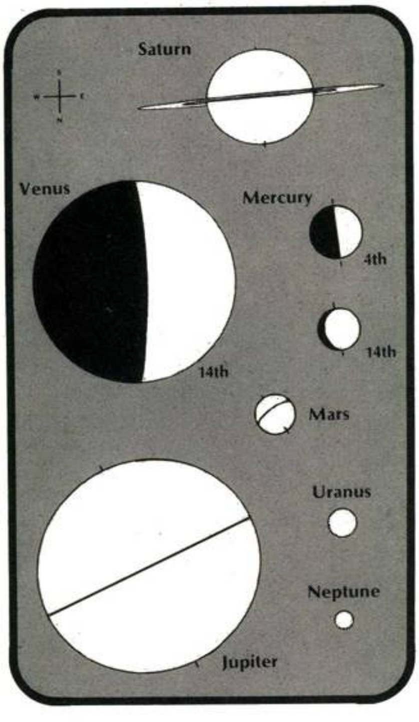
As Mercury arrives at perihelion (distance from Sun: 0.308 AU) on the 13th, it's moving very fast in its orbit — 59 kilometers per second. Only 13 days after perihelion comes superior conjunction, at 12^h UT on the 26th. If you could observe the planet, you'd see a 4.9" of arc round ball, 1.362 AU distant, lying 1° 38′ north of the Sun's center. Instead, try following the rapid phase changes day by day: from 50% lit on the 1st through 81% on the 13th as far as possible toward the fully round phase of the 26th.

Get in what Mercury-watching you can this month; the next elongation (in the evening sky on October 11th) will be hopelessly poor. But the elongation following that, in the morning sky on November 19th, will be the year's best.

Venus

Venus' movements in the morning sky above and to the right of Mercury have slowed considerably from last month. During August, the planet climbs higher (gaining 10°) and somewhat southward, passing through greatest elongation (46° west of the Sun) on August 24th. As with Mercury, greatest elongation and elevation don't coincide, elevation being highest (33°, 45 minutes before sunrise) between September 10th and 12th.

During the month of August, Venus increases its distance from us by nearly a quarter of an astronomical unit — some 35 million kilometers. This has the natural effect of reducing Venus' apparent diameter: from 32.1 arc-seconds on the 1st to 22.3 on the 31st. Its phase also alters, changing from distinctly crescent (34% lit) at the beginning of August to slightly gibbous (54%) by month's end.



Moon

On the morning of August 9th, a very thin (2% lit) crescent moon will lie about 2° to the south of Mercury in the east-northeastern sky. They'll both be very low (about 7° high 45 minutes before sunrise), but a clear sky and unobstructed horizon in that direction will allow you to view them, especially if you scan with an RFT or, better still, binoculars.

The Moon's meeting with Mars on the evening of August 15th will place a 5.2-day-old Moon a few degrees north and east of the Red Planet, which will be very low in the southwestern sky.

An occultation of Aldebaran on the morning of the 5th will be visible from all over North America except the southern half of Florida, but for people living east of the plains states, the occultation comes after sunrise.

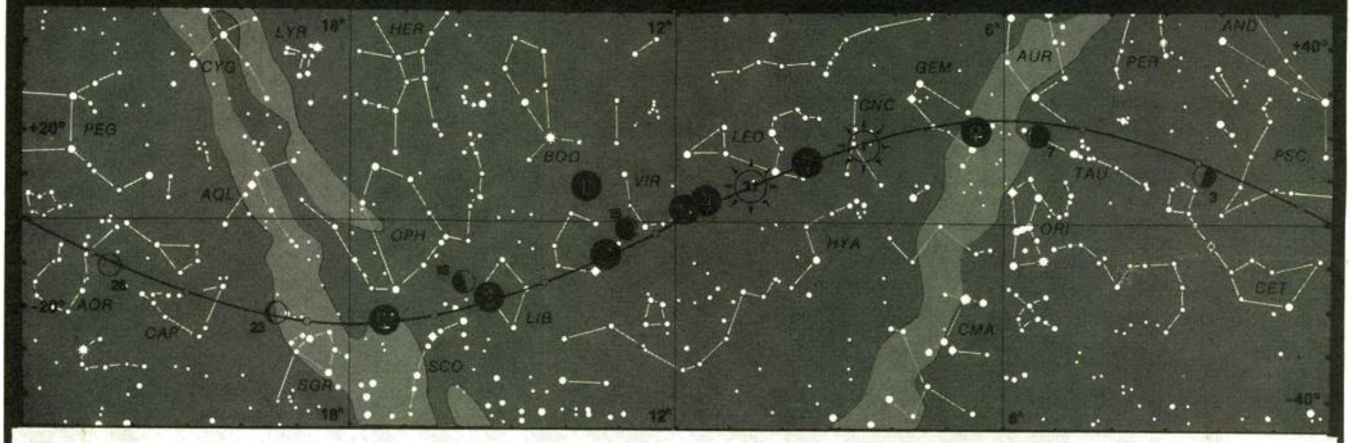
The Moon will be a thin (24-day-old) waning crescent. What with interfering twilight and the disappearance happening on the Moon's sunlit limb, you'll need a telescope to observe the immersion of the star. Reappearance, or emersion, will be easier to watch for, as the star pops out from behind the dark limb of the Moon, but growing daylight will hamper you. (Suggestion: use a red-colored filter to darken the sky.) On the west coast, reappearance comes at a time when the Sun will still be about 10° below the horizon, so these observers will be especially fortunate.

Another Moon-related event this month is our partial view of the eastern Pacific's annular solar eclipse on the 10th. (Annular eclipses happen when the Moon is too far from the Earth to cover all of the Sun's disk; an annulus — ring — of Sun surrounds the Moon.) The southwestern U.S. will see a small "bite" taken out of the Sun's southern hemisphere around midday. If you're located where you can see it, take the usual precautions for solar observing — projection methods are safest.

Mars

Low in the southwest at sundown and setting about 2 hours later, Mars offers little for the observer but the finding. On August 15th, it's 1.798 AU away, and since Mars is only 6790 kilometers in diameter (Earth measures 12,756), its apparent disk comes to just 5.2" — not much at all!

planetary data for august 1980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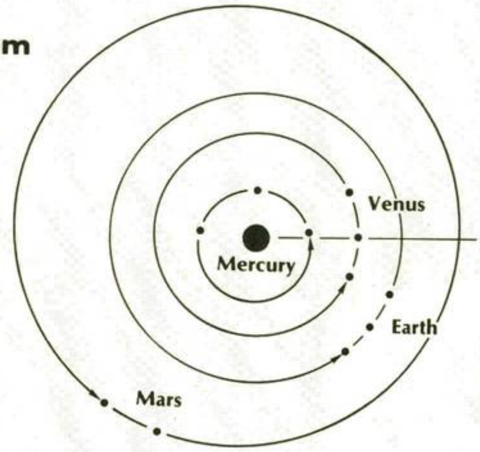
inner solar system


Venus
Mercury
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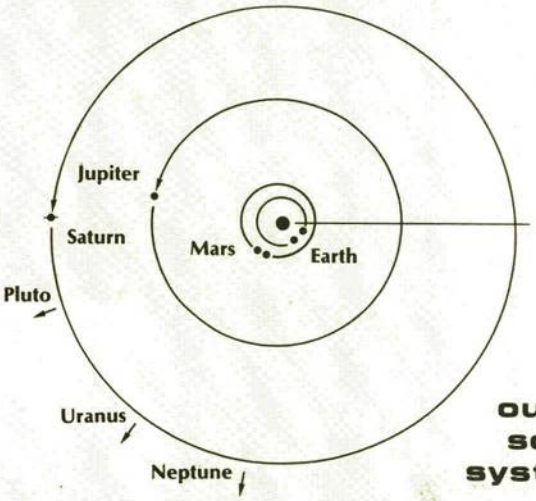

Jupiter
Saturn
Mars
Earth
Pluto
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1980.7)	Dec.
Sun		10	--	31.6′	--	1.01	--	--	137°31.2′	$9^h 19.8^m$	15°35.1′
		20	--	31.7′	--	1.01	--	--	147°07.9′	$9^h 57.3^m$	12°28.2′
Mercury	☿	10	−0.7	6.0″	84%	1.11	0.31	56°40.9′	121°06.9′	$8^h 14.9^m$	20°07.9′
		20	−1.4	5.1″	99%	1.30	0.32	118°39.7′	139°59.4′	$9^h 33.3^m$	16°13.9′
		30	−1.2	4.9″	98%	1.37	0.37	169°26.9′	159°42.6′	$10^h 49.2^m$	9°15.8′
Venus	♀	10	−4.1	28.4″	41%	0.59	0.73	352°30.8′	92°20.4′	$6^h 11.5^m$	19°16.0′
		30	−4.0	22.5″	53%	0.75	0.73	8°25.1′	110°39.5′	$7^h 29.3^m$	19°13.3′
Mars	♂	15	+1.4	5.2″	94%	1.80	1.54	235°09.3′	200°31.0′	$13^h 17.0^m$	−8°18.6′
Jupiter	♃	15	−1.2	28.9″	100%	6.35	5.43	168°31.3′	164°03.8′	$11^h 04.4^m$	7°04.1′
Saturn	♄	15	+1.3	14.5″	100%	10.32	9.49	178°53.5′	175°07.0′	$11^h 46.9^m$	3°41.1′
Uranus	⛢	15	6.1	3.7″	--	18.75	18.77	234°42.0′	231°25.1′	$15^h 17.0^m$	−17°55.1′
Neptune	♆	15	7.8	2.5″	--	29.80	30.28	261°40.8′	259°31.7′	$17^h 16.9^m$	−21°41.3′
Pluto	♇	15	14.0	--	--	30.65	30.12	201°17.2′	199°27.8′	$13^h 36.3^m$	8°05.3′

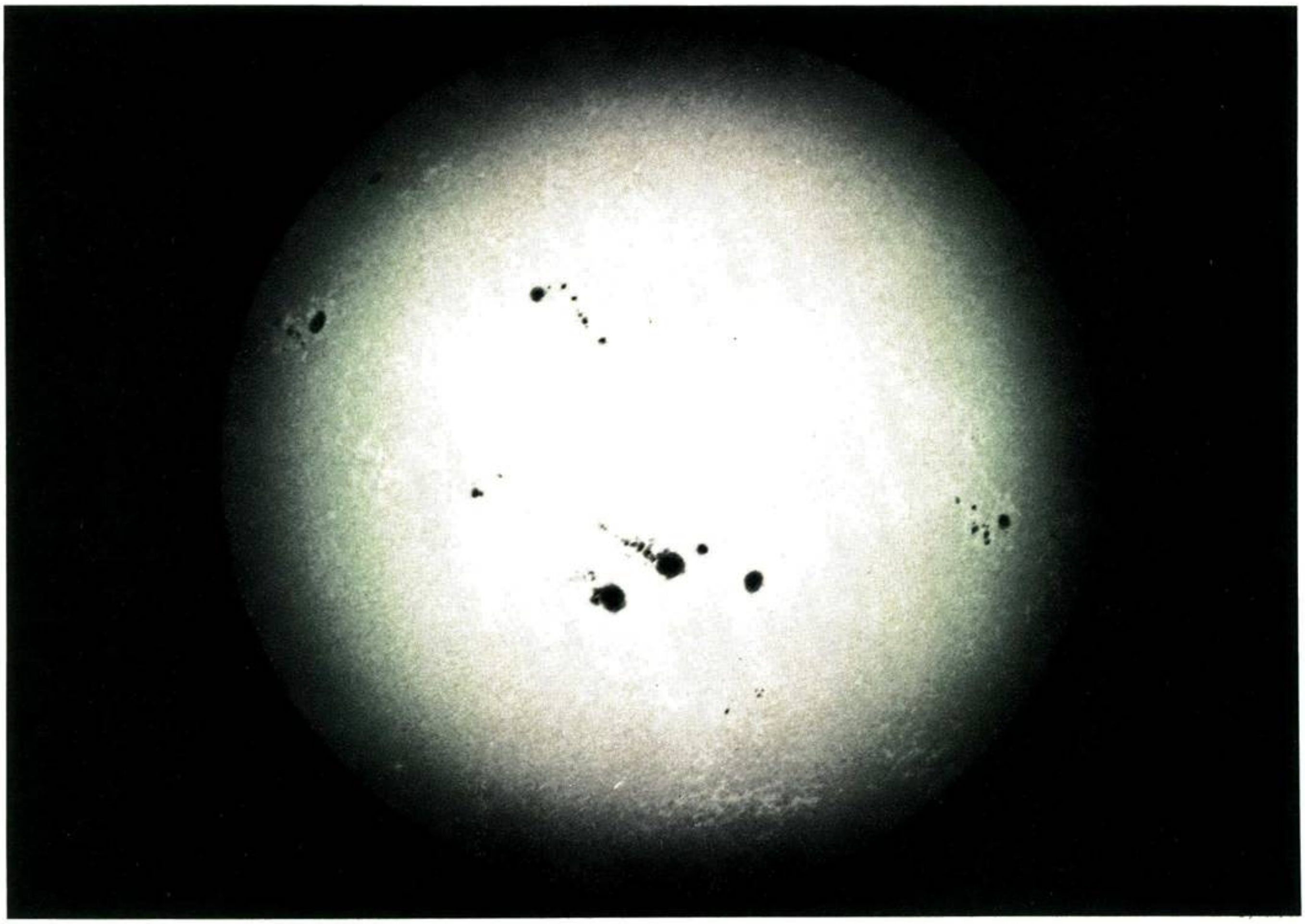
moon data

Last quarter	August 3 at 12:00
New moon	August 10 at 19:09
First quarter	August 18 at 22:28
Full moon	August 26 at 03:42
Last quarter	September 1 at 18:08

Apogee: August 15 at 18h	405,245 km
Perigee: August 27 at 19h	360,875 km

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.



Taken late in May, Andrew Steinbrecher's photo captures the unquiet Sun: spots and faculae mar its brilliant disk. The large group at lower center was visible to the naked eye. Steinbrecher used a 16" f/5 stopped down to a 6" aperture, a solar filter, and 1/125 sec. exposure onto Kodak High-Contrast Copy film.

Asteroids

1 Ceres is in western Gemini on August 15th at $6^h\ 11^m\ 3^s$, +22° 47′ 28″ (1950 coordinates). The magnitude 8.0 object won't be too easy to find since it rises only a couple of hours before the Sun does.

2 Pallas lies at $2^h\ 30^m\ 33^s$, -2° 46′ 42″ (1950) on the 15th. This is in Cetus, which makes the magnitude 8.4 asteroid a morning object.

3 Juno on the 15th is about a month away from conjunction (September 17th) with the Sun and hence nearly impossible to find.

4 Vesta was in conjunction late in June; it's now in the morning sky and hard to find because it rises shortly before the Sun does. Look for the magnitude 8.2 object at $7^h\ 51^m\ 3^s$, +21° 11′ 44″ (1950), on the Cancer/Gemini border.

7 Iris is in eastern Pegasus (at $0^h\ 0^m\ 53^s$, +10° 48′ 54″, 1950 coordinates) on August 19th; it's at magnitude 9.1.

Jupiter

You may catch sight of Jupiter briefly at the beginning of the month, but it'll soon vanish into the western twilight at sunset. On the 1st, Jupiter is 7.6° high 45 minutes after sundown; by the 12th, this'll become only 3.3°. Conjunction comes about the middle of next month, on the 13th of September.

Saturn

Only a short distance east of Jupiter, Saturn, too, sets soon after the Sun. Beginning the month with an altitude of 14° (45 minutes after sunset), Saturn sinks day-by-day until it's 1° high (again: sunset + 45 minutes) on the 31st.

Uranus

Uranus is becoming harder to find because Libra, its "home" constellation, is a late spring-early summer group that sets by 10 or 11 p.m. local daylight time.

Start at Gamma (γ) Librae with a low-power eyepiece on your telescope. Scan south almost 2° and west about half a degree. Three 6th magnitude stars here form a flat open triangle. Uranus lies 2½° west and 1½° south of the westernmost star. Its 3.6″ diameter disk has a magnitude of 5.9.

Neptune

Magnitude 7.7 Neptune has a disk 2.4″ in diameter. Look for it in southeastern Ophiuchus to the north of 3rd magnitude Theta (θ) Ophiuchi. Center Theta in a low-power eyepiece and sweep directly north 3°. Neptune's disk will pass through your field of view at its western edge.

Meteors

It's Perseid time again! This year, the best of the annual showers will have a perfect setting for your observations. The Moon on the night of August 11th to 12th (time of peak activity) will be only 1 day old and setting very soon after the Sun does; plan on dark skies the whole night through.

The "zenithal hourly rate" (an idealized average) for the Perseids is 68, but few observers will see that many. A more likely figure from a good rural or dark suburban site is 45 to 50 an hour (excellent years have doubled this number). City observers won't see more than about 5 or 6 per hour since the sky background washes out all but the very brightest.

Remember that most activity happens after local midnight — 1 a.m. by daylight time — so don't pack it in too early. Take the time to get comfortable (but don't go to sleep) and plan on staying up a long time. By the way, Photography in Astronomy this month has some ideas on how to photograph the shower.

Far above the cloudbelts of Jupiter, two of the giant planet's moons pursue their endless orbits. Look closely: the shadow of one of them lies on the disk. Craig McCaw took this photo with a 16" on British Columbia's Mt. Kobau. He used Kodachrome 64 and a 1-second exposure with eyepiece projection.

close-up on aquila

This little constellation, seen as an eagle since far back in antiquity, is curiously neglected — especially in comparison with its companions of the Summer Triangle, Cygnus and Lyra. Perhaps because it has none of the famous "name" objects, observers tend to skip past this short stretch of Milky Way as they hunt for the better-known sights in neighboring groups. But let's avoid that trap and see what others have overlooked.

The natural place to begin a tour of Aquila is at its brightest star, **Altair**. A white star of spectral class A7, Altair is about 50% larger than the Sun, substantially hotter (8100° K as opposed to 5800° K), and about 10 times more luminous. Its intrinsic brightness and relative closeness (16 light-years) combine to make it the 12th brightest star in the sky.

So far as known, it's not part of any double or multiple system, though a dim (10th magnitude) companion can be seen with high power to the west-northwest (position angle 301°) at a separation of 165" of arc. This companion is surely an "optical double" for there's been no trace of orbital motion in the 140+ years since it was first detected. The slow increase in separation over the years (it was 152" at discovery) is a reflection of the two stars' different proper motions.

Yet despite Altair's blandness, there's something irresistible about gazing into the fiery heart of a first magnitude star. The light seems almost alive as it wiggles around in the usual bad seeing. You can almost believe that there's this immense, fiercely hot candle out there flickering in some celestial breeze. Of course, it's just the Earth's atmosphere, but the impression is hard to shake, nonetheless.

Leaving Altair, let's turn our attention to a real double star — **Pi (π) Aquilae**. Lying 3° north and ¾° west of Altair, this 6th magnitude object can be located most easily if you swing your scope west the amount needed and then north. Depending on the size of your field of view, you may catch 3rd magnitude Gamma (γ) slipping through the western edge of your field as you scan north. Since Gamma lies 2° north of Altair, use it as a guide on your way to Pi.

The two stars that make up Pi shine at 6.2 and 6.8 magnitudes respectively. They're a close pair: separation is only 1.4" (in position angle 108°), but with a 4 to 6-incher, 150x on a good night will split them. In the mid-19th century, Webb noted that they were "not single" for him at 80x and were seen "very close" at 144x.

Their colors have been variously reported, perhaps because the hues aren't very strong at all (and perhaps also because the components lie so close together). Webb called them yellow and green and listed the colors noted by others, ending with typical understatement, "great divergence as to color." Their spectral types are F2 (yellowish) and A2 (white) and so the note in the Webb Society's *Handbook* of "pale blue and grey" seems about right if we allow for some subjectivity.

From Cygnus down into Aquila and beyond runs the so-called **Great Rift** of the Milky Way. Something of a misnomer (though descriptive enough), the Rift really consists of a lane of dust in the plane of the Galaxy obscuring distant clouds of stars. Most of it looks like a dark swath with fuzzy edges, but here and there a blacker, more distinct blob can be picked out — especially on long-exposure photos.

Our next object is one of these dark nebulae and one of the few that can be discerned by eyeball at the telescope. Known cryptically as **B-143**, it's an irregularly shaped mass with an apparent diameter about that of the Moon (30′ of arc).

As you can see from the map, the easiest way to find it is to center on Gamma and sweep about 1½° west. This won't be an easy object — a dark night and a large-aperture (8″ or more), low f/ratio optical system is a must. When you gaze at it, let your imagination reach out to this "tiny" cloud of celestial soot — it's probably several dozen light-years across, but so what? — and see if you can perceive the three-dimensional effect of a dust cloud in front of distant stars that Robert Burnham Jr. mentions.

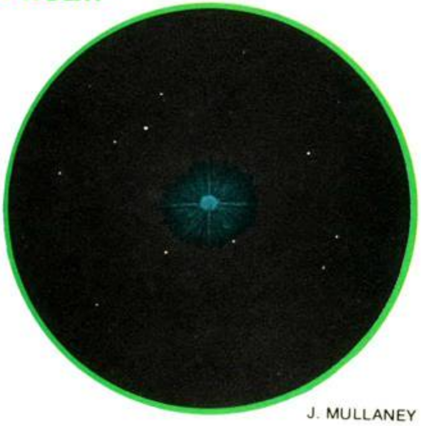
Moving on to the next object, the open cluster **NGC-6709**, let's return to Gamma as a jumping-off point. When Gamma has been centered in your low-power eyepiece, sweep due west (past B-143) nearly a full hour of right ascension: 55^m (or 14°). There, only a few minutes of arc to the south you'll find NGC-6709, a glittering little spray of stars.

Because the cluster has a diameter of about 12′ of arc, use medium powers to get all of the 40 or so cluster members into your eyepiece. Their combined light sums to that of an 8th magnitude star, though the individual members range from 9th magnitude or so on down to 12th and beyond. Since the cluster is relatively compact, it clearly isn't very old; random internal motions and the perturbing influences of the Galaxy haven't yet had time enough to disrupt it.

Two degrees south and 15^m east of NGC-6709 we come to a variable star, **R Aquilae**. One of the class of long-period variables of which Mira (Omicron Ceti) is best known, R Aql

Right: The Sun rises over Theophilus, Cyrillus, and Catharina, three large craters on the western rim of Mare Nectaris. Photo by Jack Metcalfe of Lexington, Kentucky. Below: Bill Iburg's shot of NGC-4565 shows the dust lane and the bulge of its central region. Our Milky Way edge-on would look like this.

Altair

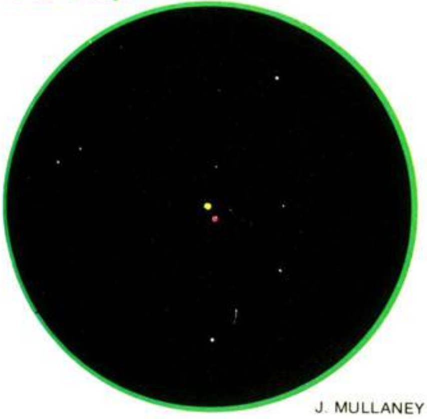


J. MULLANEY

B-143

LICK OBS.

15 Aql



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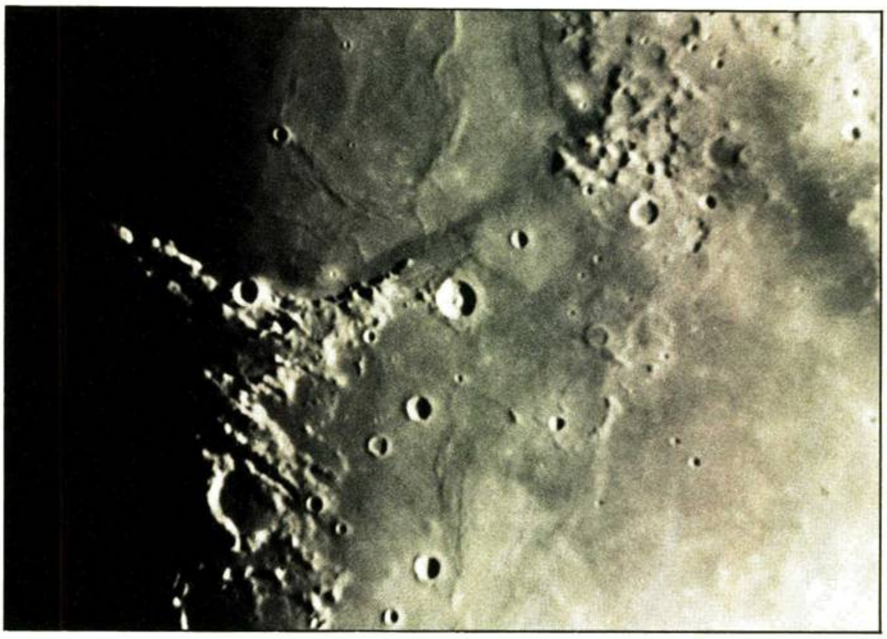
NGC-6709

LICK OBS.



In the "straight" between Mare Serenitatis (top) and Tranquillitatis (below) lies the crater Plinius, 43 kilometers in diameter and having a bumpy central peak. Exploring this region with a telescope will reveal several rilles just to the north of the crater. Jack Metcalfe used a C-8 and Plus-X at f/64 for 1 second.

has a period of 293 days and a magnitude range from about 6th magnitude to 12th. Its spectral type is "late," varying from M5 to M8, which explains its reddish color.

R Aql will be at minimum light early in September, so unless you have a scope 6" or larger, you're going to have trouble locating it now. Since the next maximum is scheduled for January 15th, 1981, why not put it on your weekly observation list and watch the slow rise over the next few months?

An interesting if not unique feature of R Aql is that its period is gradually shortening. Robert Burnham Jr. notes that it has shed 50 days off its cycle over the last 80 years. How much longer this will go on isn't known; the period may stop shortening, or even commence lengthening again, if it reaches some minimum.

Twelve and a quarter degrees south and a couple of minutes west of R Aql lies a pretty double star system — **15 Aquilae**. Consisting of magnitudes 5.5 and 7.2 stars, the components currently are a wide 38" apart (at position angle 209°), which puts them in easy reach of even 60 mm refractors (try about 25 to 30x). A larger telescope and more power will bring out a color difference between them, the primary usually being seen as yellowish-white and the other as a ruddy lilac.

Sweep south from 15 Aql a distance of 4° and eastward 50 minutes of right ascension and you arrive at another double very suitable for small telescopes, **57 Aquilae**. (Don't confuse it with 56 Aquilae 1/3° to the south — 56 is distinctly yellower and over a magnitude dimmer.)

Like 15 Aql, 57 is widespread: 36" of arc (in position angle 170° — nearly north-south), but unlike it, the colors of the components are virtually identical. Their spectral types are B8 and B5, so if you see any color discrepancy it's likely a subjective effect.

The last two items on this month's roster are both variables, one intrinsic, the other extrinsic. **Eta (η) Aquilae**, lying 8° south of Altair (or sweep 9½° north from 57 Aql), is a cepheid variable, a class named after its prototype Delta Cephei, and it's one of the brightest of that type. Over a period of 7 days 4¼ hours, it swings between a maximum brightness of 3.7 magnitude down to a minimum light of 4.5. (Naturally, this places it within the reach of naked-eye observations and you may wish to follow it that way.)

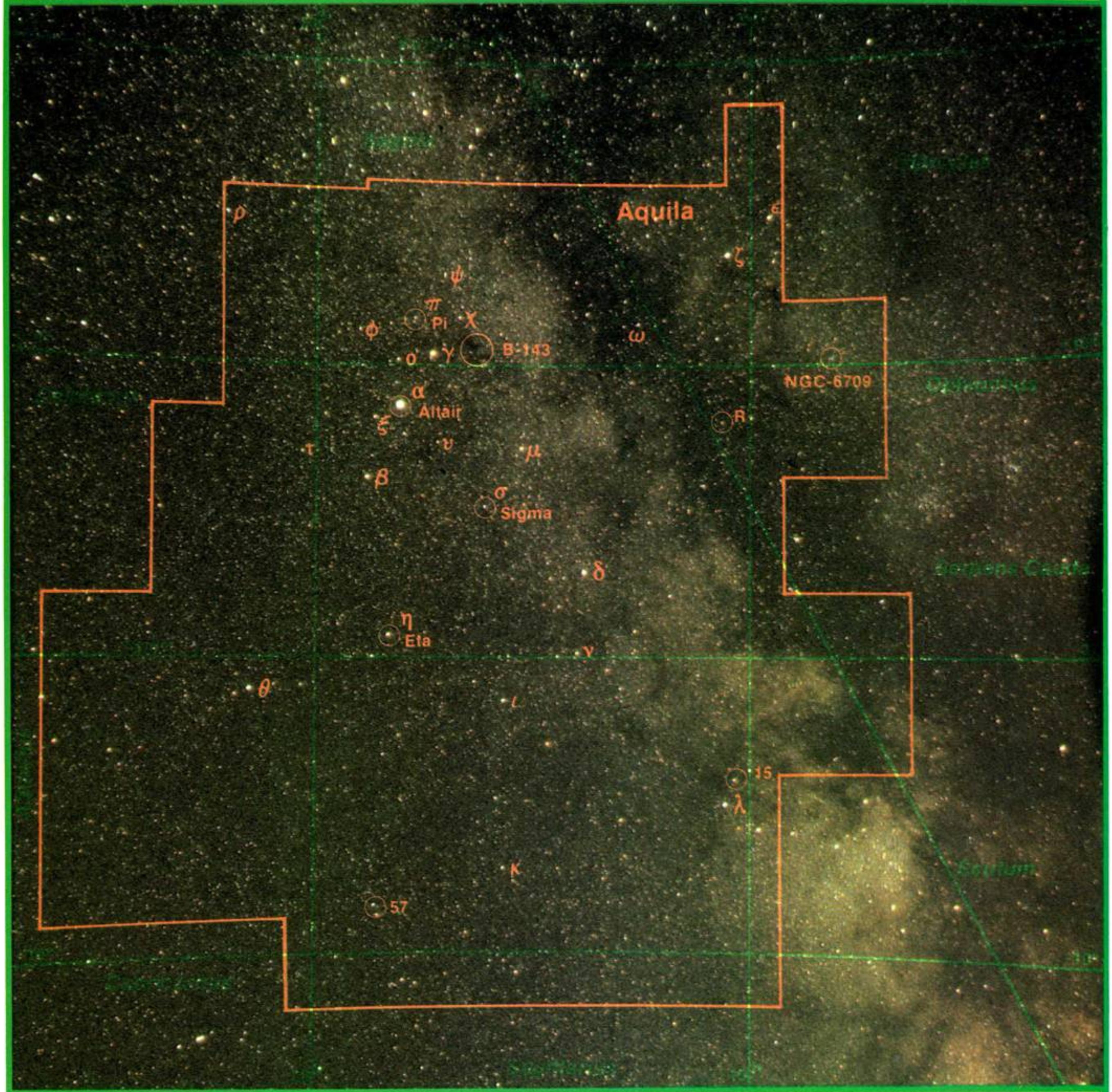
Whereas the other two variables mentioned this month change their brightness by physical changes in the star itself, **Sigma (σ) Aquilae** differs in that its variations are caused by a happenstance of geometry.

It's an eclipsing variable, that is, a binary system in which one component periodically blocks some or all of the light from the other. In this case, the blocking is only partial and the resulting magnitude drop is just 0.2 magnitude. This small difference will be hard to detect at first; the larger the telescope you have, the easier you'll find the task. Sigma's period is just under 2 days (46.8 hours) and so looking on any clear night will reveal a change — if your eyes can spot it!

aquila

Map by Dewey Schwartzenburg

Photo by R. Provin & B. Wallis


Aquila
ρ
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Pi
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B-143
NGC-6709
Ophiuchus
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57

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1980)	Dec.
NGC-6709	○	8.1	12′	18^h49^m	+10°17′	18^h51^m	+10°19′
15	★²	7.2,5.5	38″	19^h02^m	–04°06′	19^h04^m	–04°04′
R	ᗰ★	5.5-12.0	293^d	19^h04^m	+08°09′	19^h05^m	+08°12′
Sigma (σ)	Ӿ★	5.0-5.2	1.95^d	19^h37^m	+05°17′	19^h38^m	+05°21′
B-143	□	--	30′	19^h38^m	+11°00′	19^h39^m	+11°04′
Pi (π)	★²	6.2,6.8	1.5″	19^h46^m	+11°41′	19^h48^m	+11°46′
Alpha (α)	★	0.8	--	19^h48^m	+08°44′	19^h50^m	+08°49′
Eta (η)	ᗰ★	4.0-5.4	7.18^d	19^h50^m	+00°53′	19^h51^m	+00°57′
57	★²	5.8,6.5	36″	19^h52^m	–08°22′	19^h54^m	–08°17′

★	*Star*
★²	*Double Star*
★³	*Triple Star*
ᗰ★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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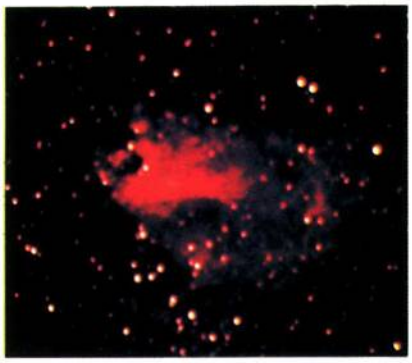

The Omega Nebula (M17) as
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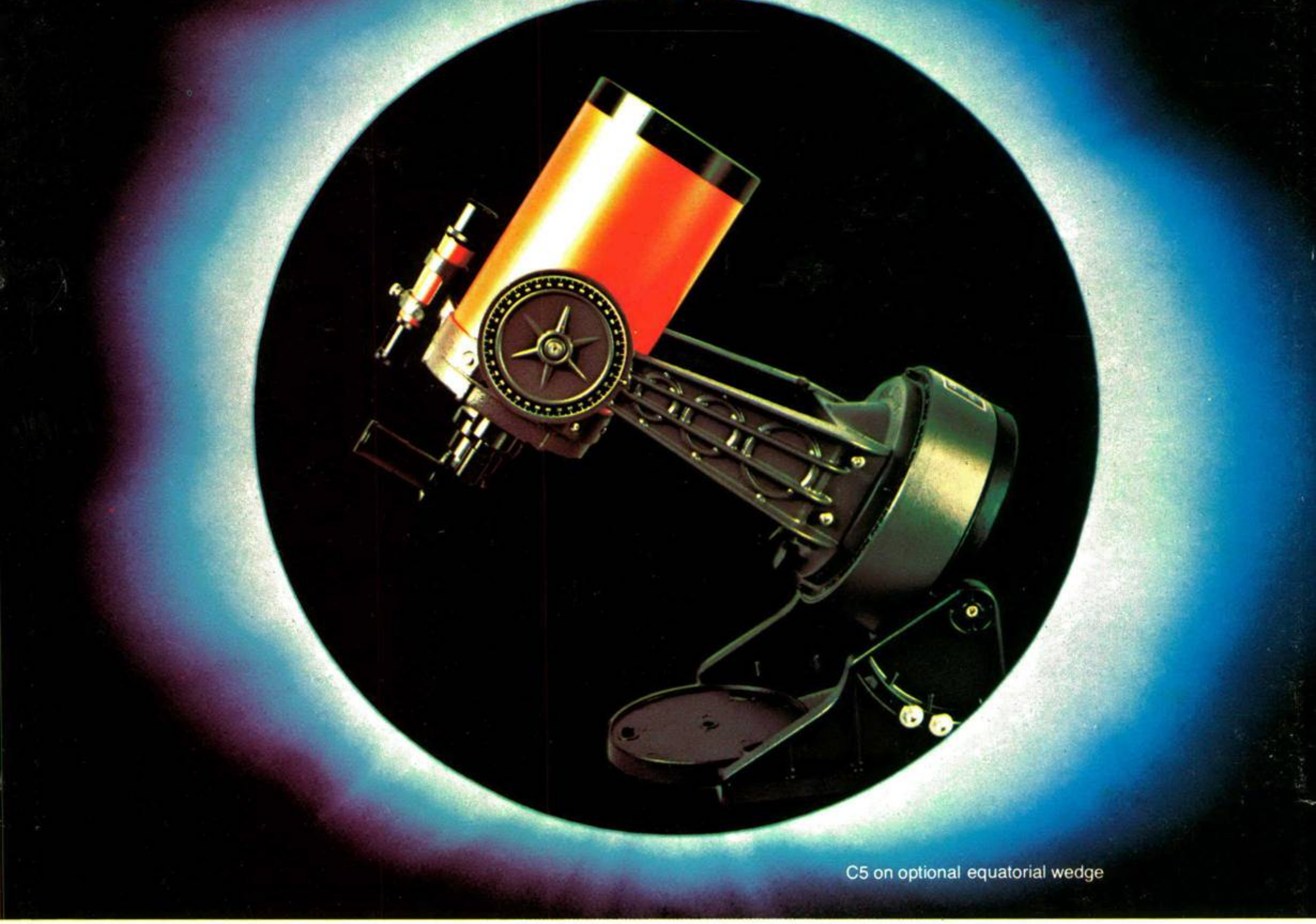
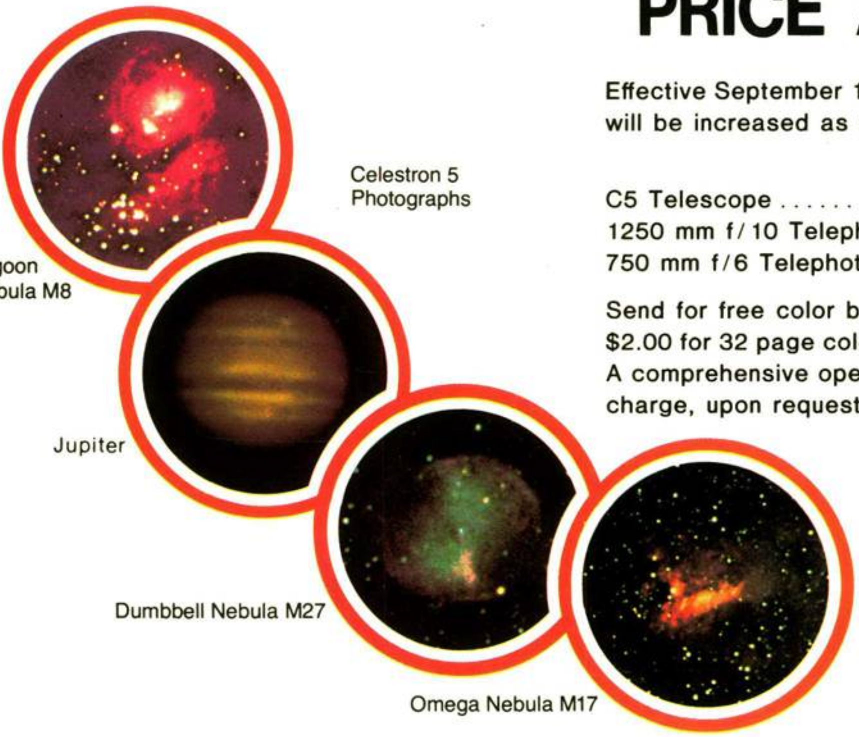


C5 on optional equatorial wedge



Celestron 5 Photographs

Lagoon Nebula M8

Jupiter

Dumbbell Nebula M27

Omega Nebula M17

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